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METALLURGIA

THE BRITISH JOURNAL OF METALS

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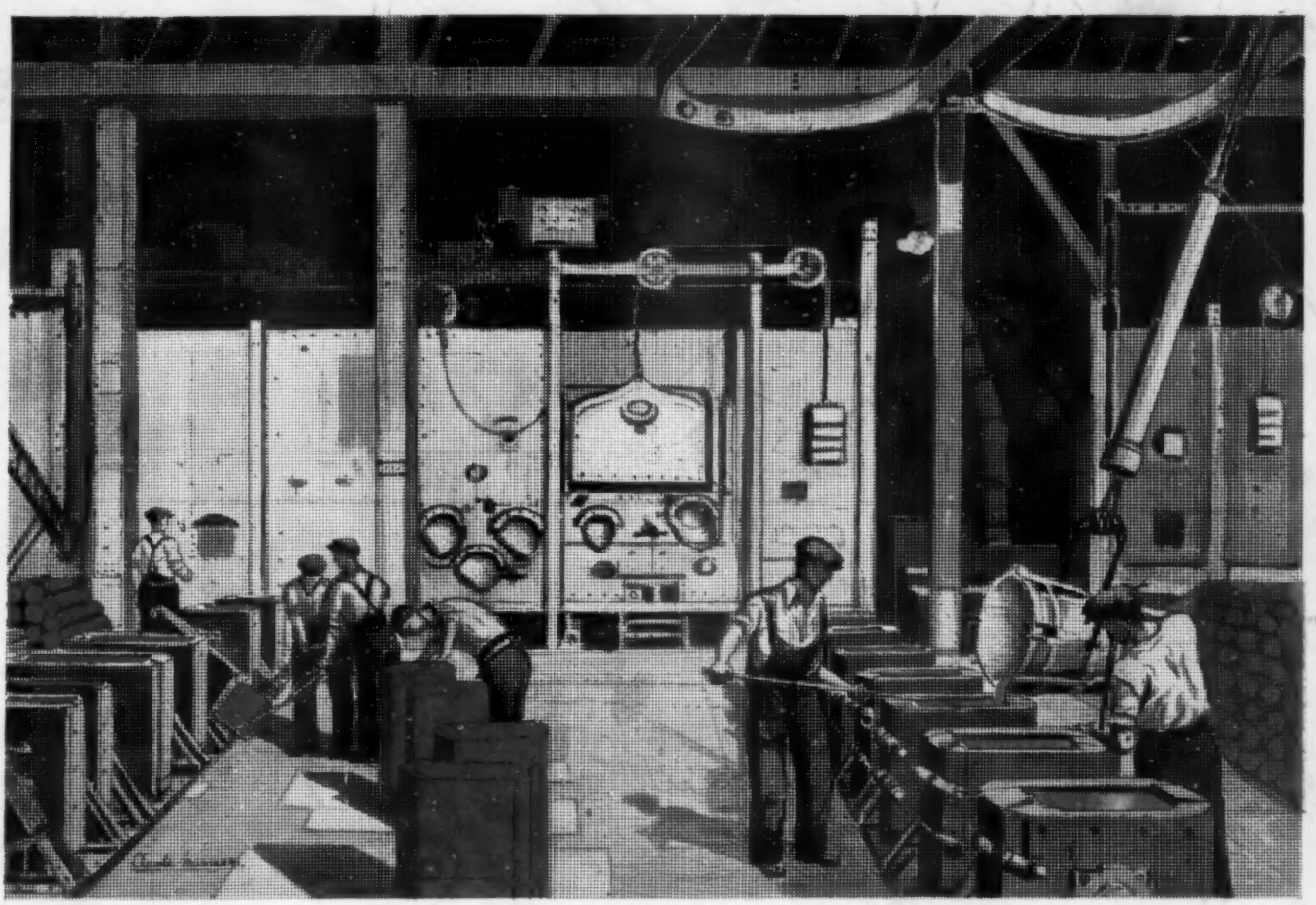

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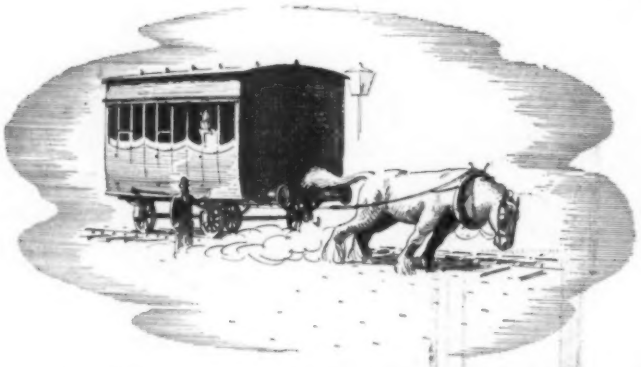

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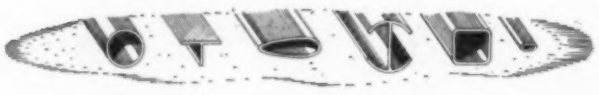

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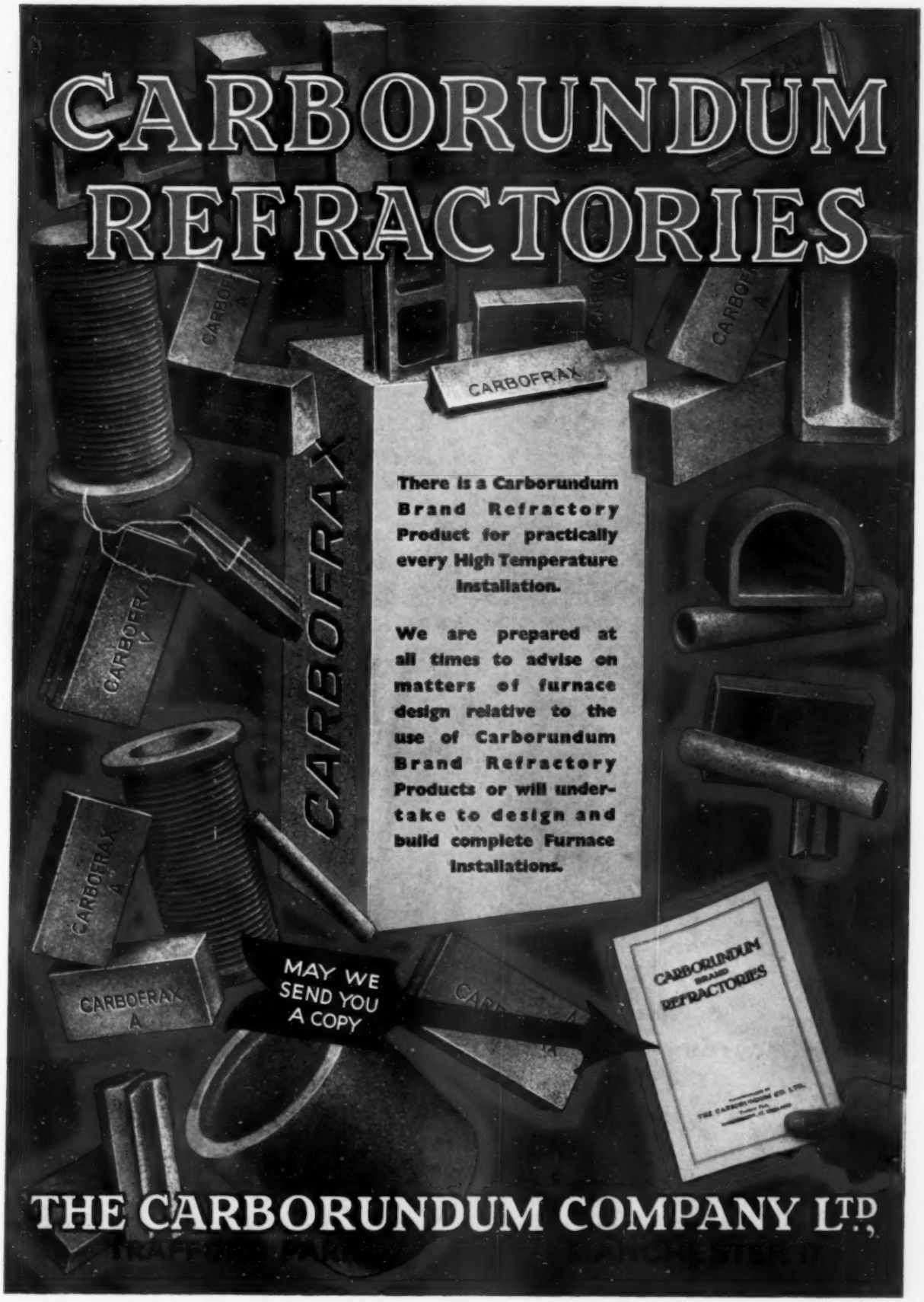
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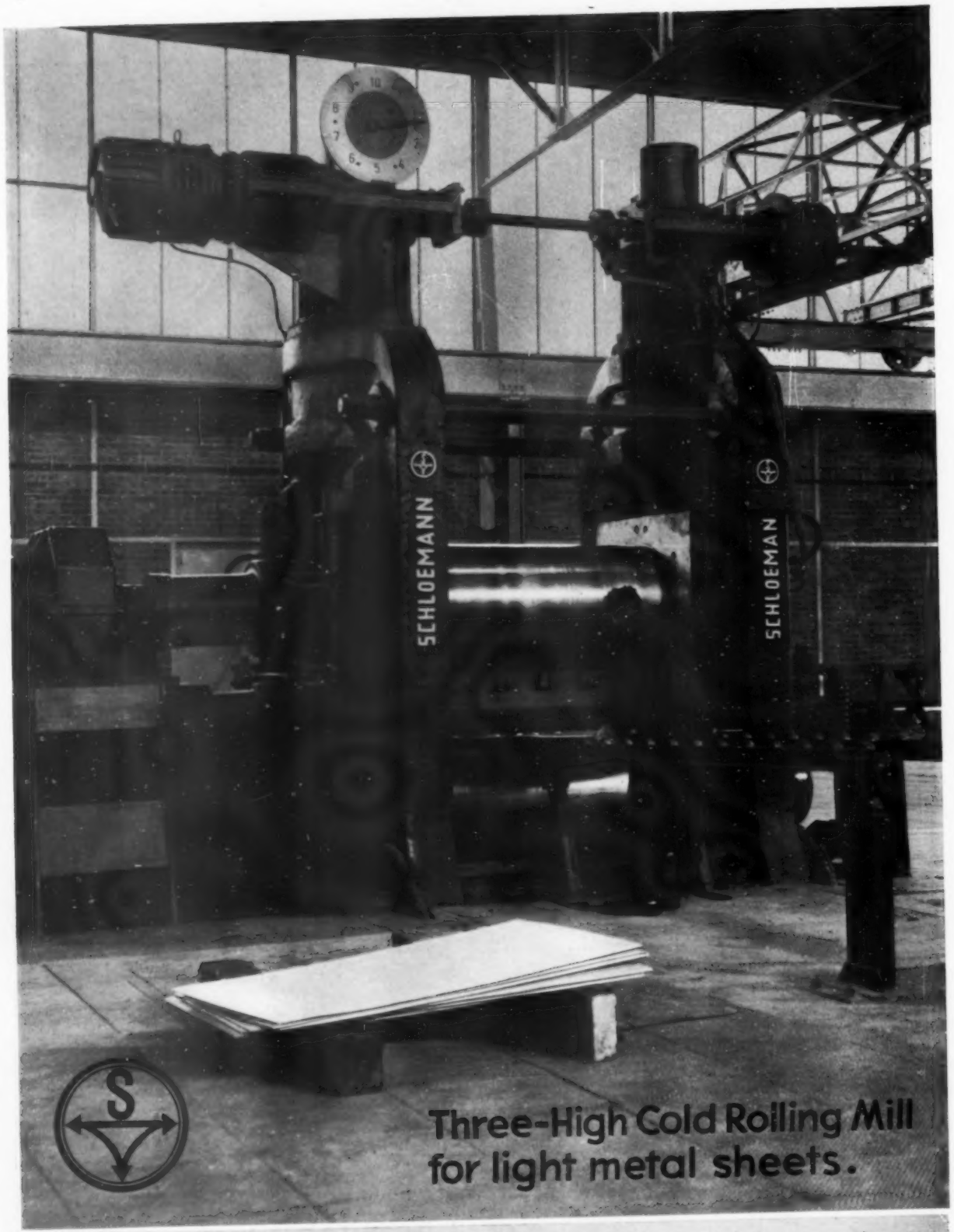

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Complete properties overleaf.

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	Solution treated and artificially aged	Solution treated and naturally aged	Annealed
In tension: Proof stress (0.1%) tons/sq. in.	28 - 33	18 - 21	4.0-8.0
Ultimate stress tons/sq. in.	33 - 38	29 - 32	12 - 14
Elongation on 2" G.L. %	16 - 10	21 - 16	20 - 14
Brinell Hardness Number	160-180	130-140	45-65

HIGH DUTY ALLOYS LTD., SLOUGH

T.G.S.

"HIDUMINIUM" R.R.77

Physical Properties

SPECIFIC GRAVITY	2.80
SPECIFIC WEIGHT lbs. per sq. inch	0.101
CO-EFFICIENT OF THERMAL EXPANSION ... 20 - 100°C.	20×10^{-6}
20 - 200°C.	22×10^{-6}
20 - 300°C.	23×10^{-6}
20 - 400°C.	25×10^{-6}
ELECTRICAL CONDUCTIVITY	
Solution treated and artificially aged. Reciprocal ohms per Cm^3	200,100
Solution treated and naturally aged. " " " "	185,800
Annealed ... ... " " " "	261,000
THERMAL CONDUCTIVITY (calculated)	
Solution treated and artificially aged. In C.G.S. units	0.340
as a percentage of copper	37
Solution treated and naturally aged. In C.G.S. units	0.320
as a percentage of copper	34
Annealed ... ... In C.G.S. units	0.421
as a percentage of copper	44.5
YOUNG'S MODULUS (E.) lbs. per sq. inch	10.0×10^6
FATIGUE Endurance limit at 20×10^6 cycles tons/sq. in.	±12.5 - 13.0

General Mechanical Properties

HEAT TREATMENT	IN TENSION			IN COMPRESSION		BRINELL HARDNESS NUMBER
	Proof stress (0.1%) tons/sq. in.	Ultimate stress tons/sq. in.	Elongation on 2" G.L.%	Proof stress (0.1%) tons/sq. in.	Proof stress (0.5%) tons/sq. in.	
Solution treated and artificially aged	28 - 33	33 - 38	16 - 10	27 - 30	32 - 36	160 - 180
Solution treated and naturally aged	18 - 21	29 - 32	21 - 16	17 - 21	22 - 25	130 - 140
Annealed	4 - 8	12 - 14	20 - 14	4 - 8	7 - 9	45 - 65

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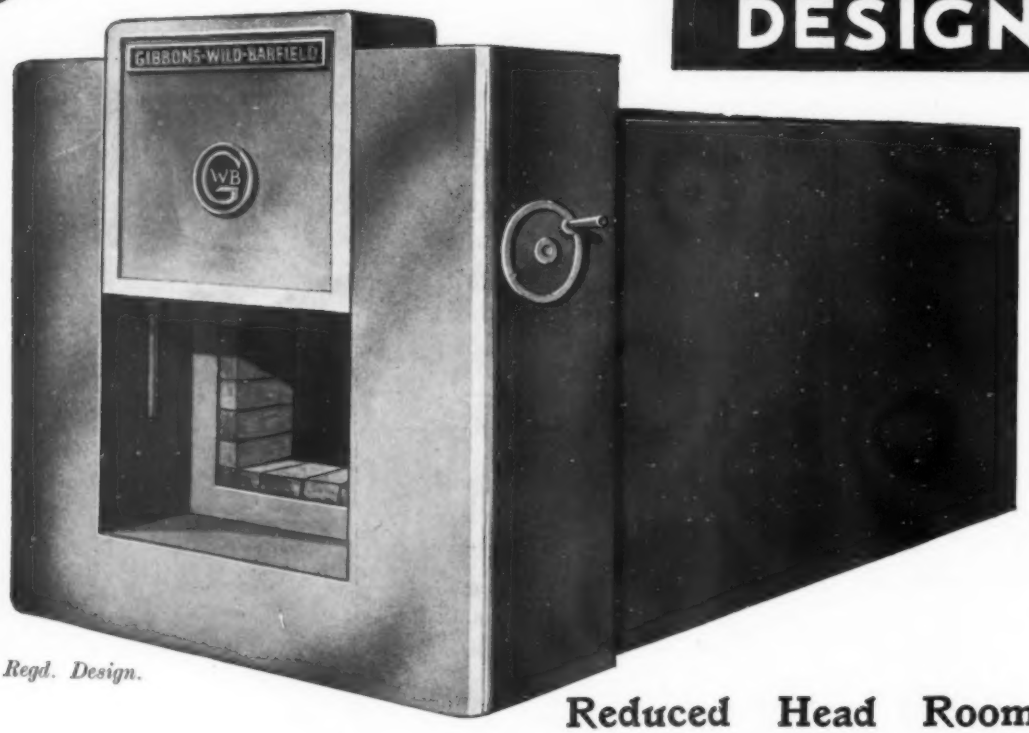

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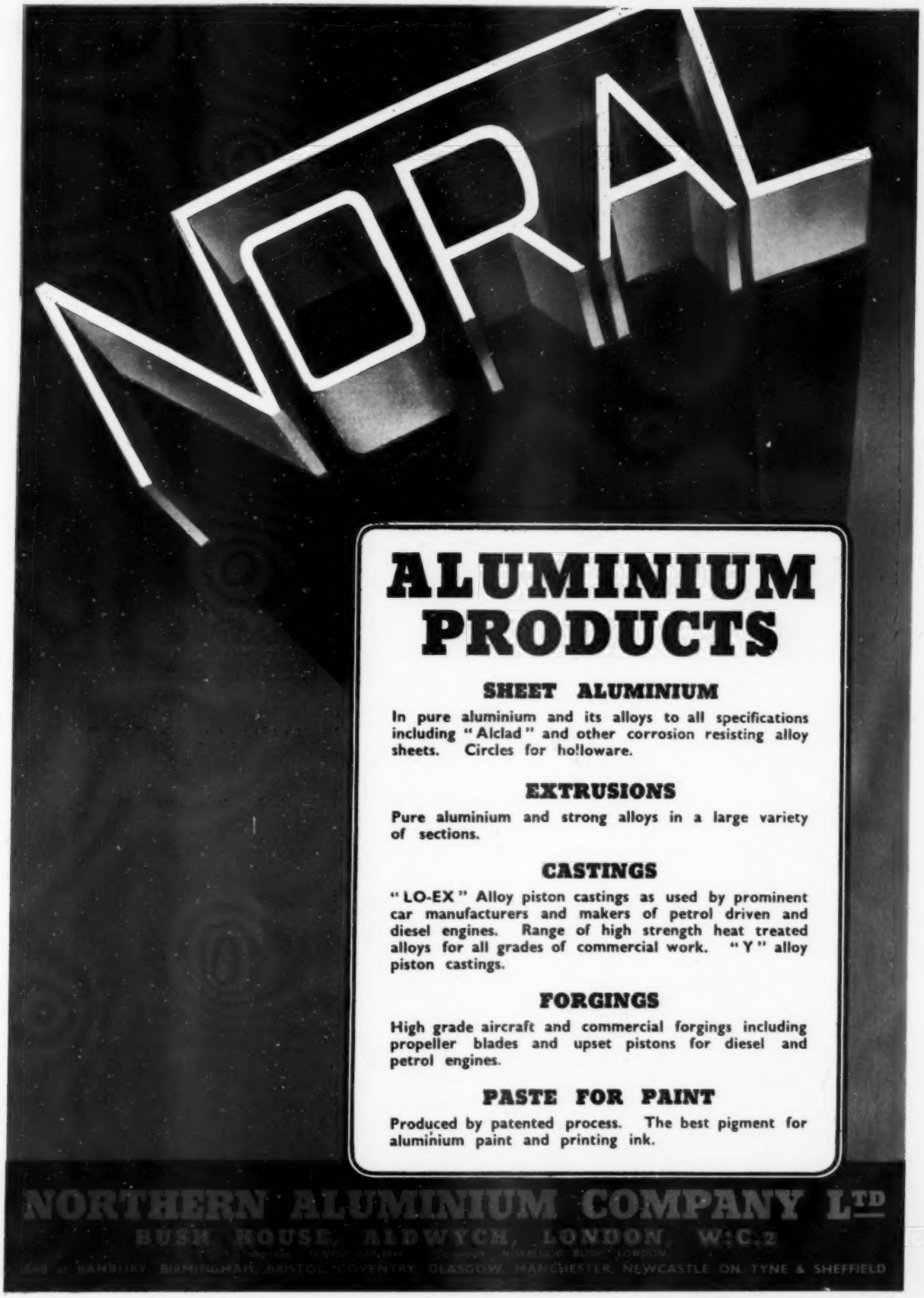
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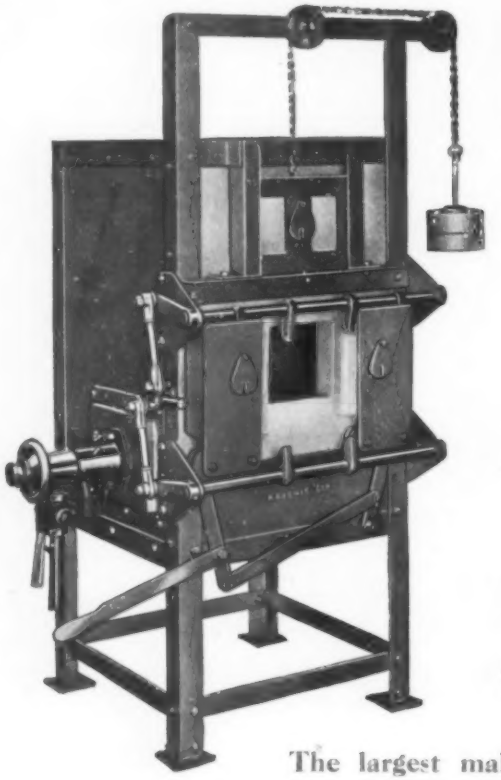

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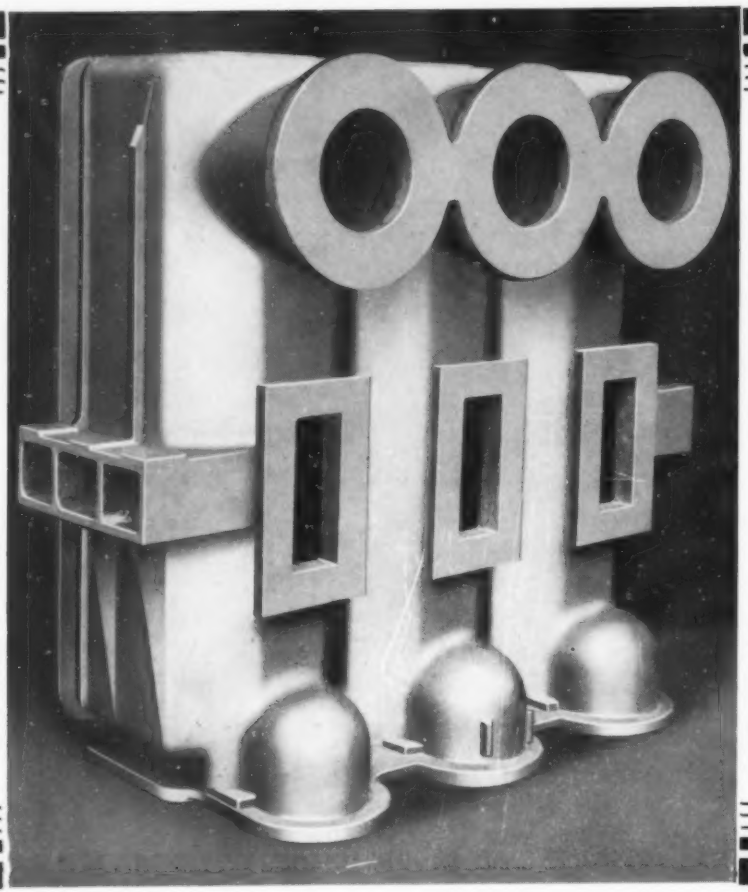

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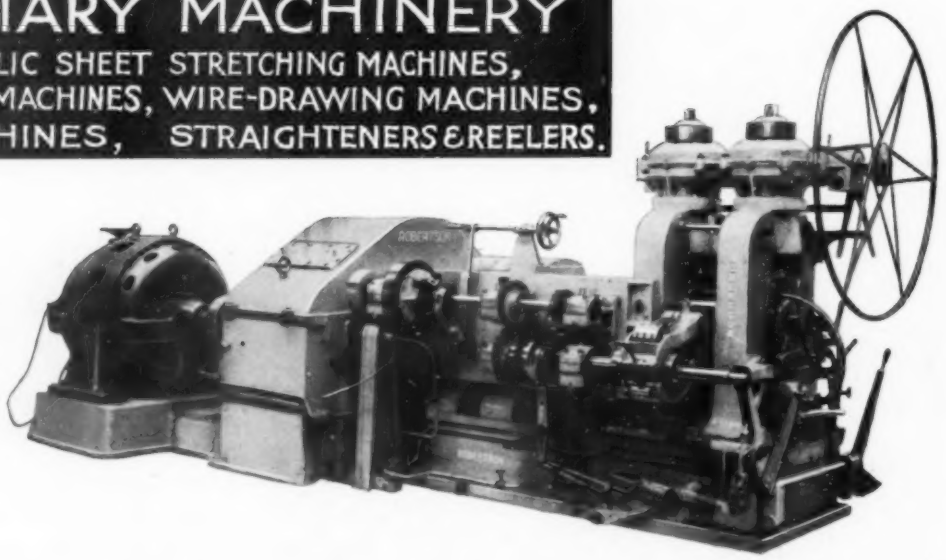

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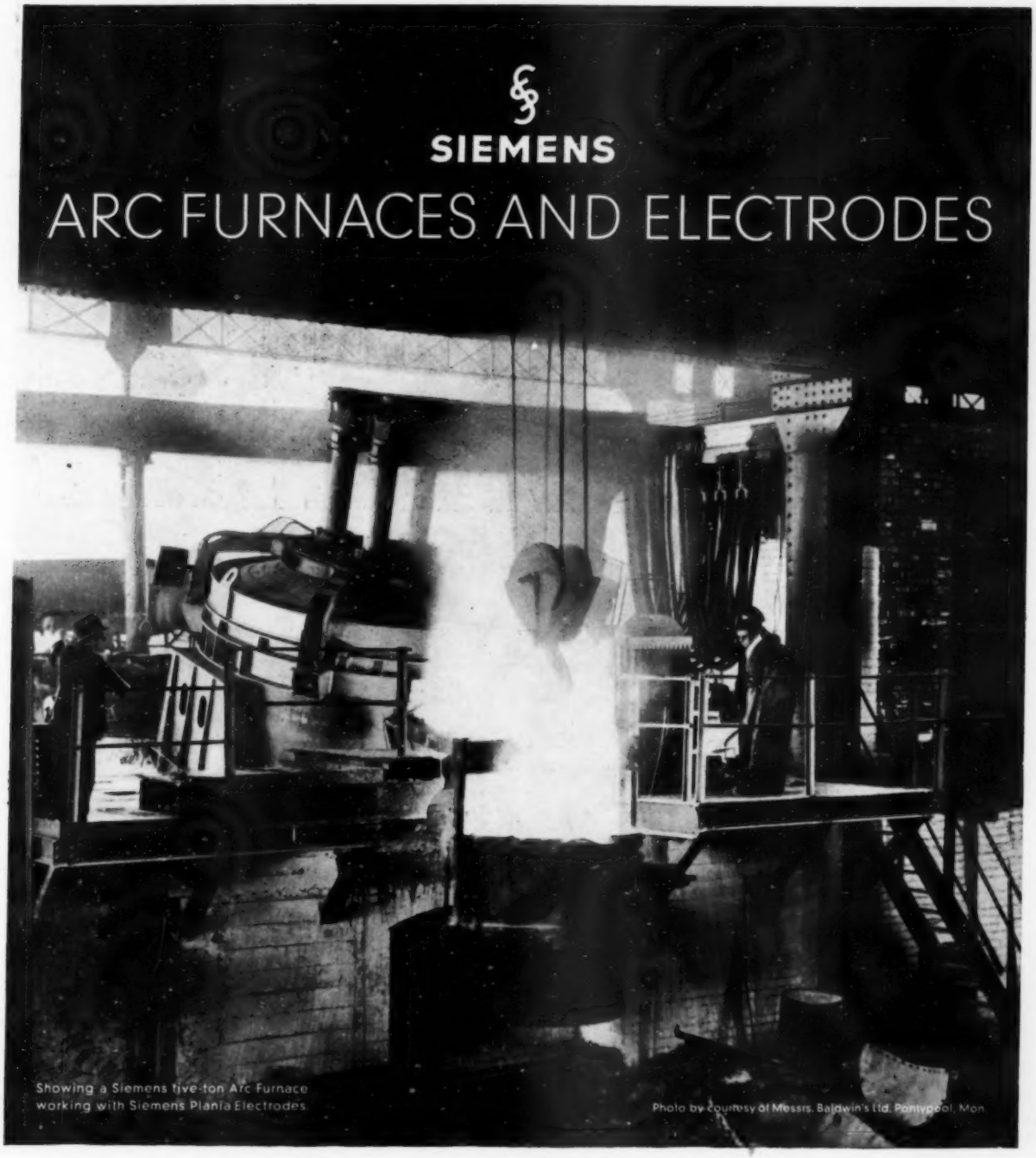
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Showing a Siemens five-ton Arc Furnace working with Siemens Plania Electrodes
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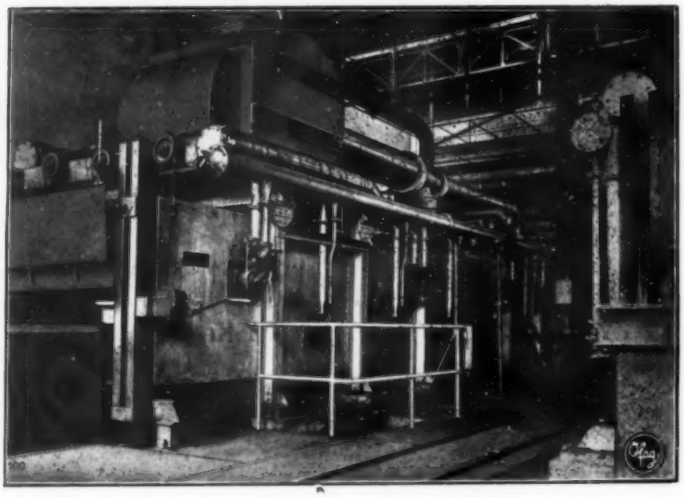

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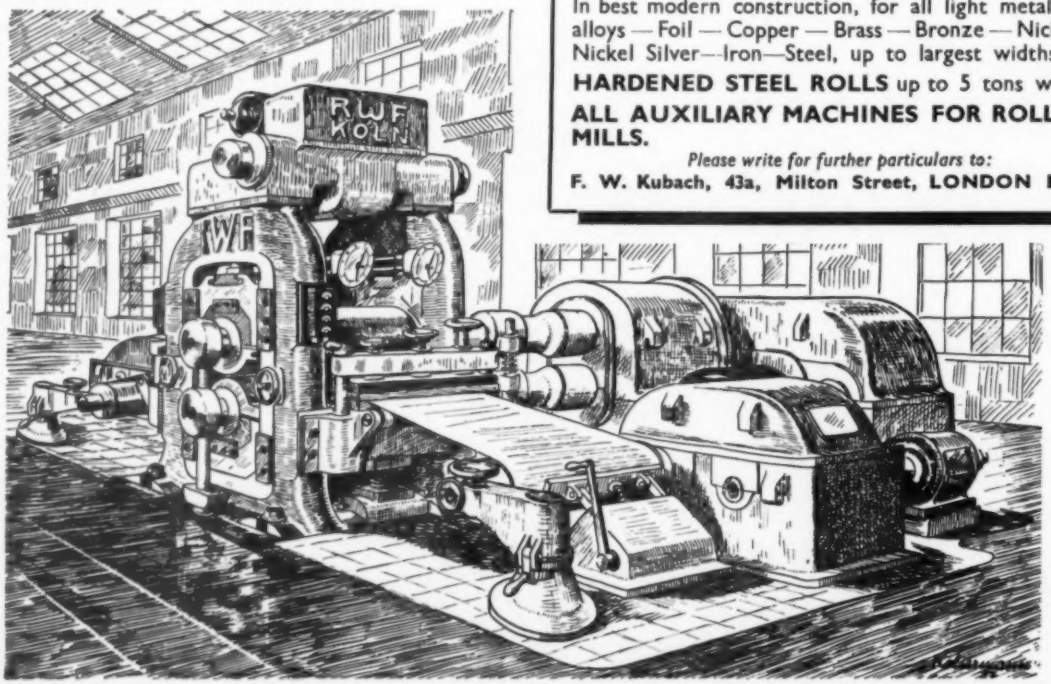

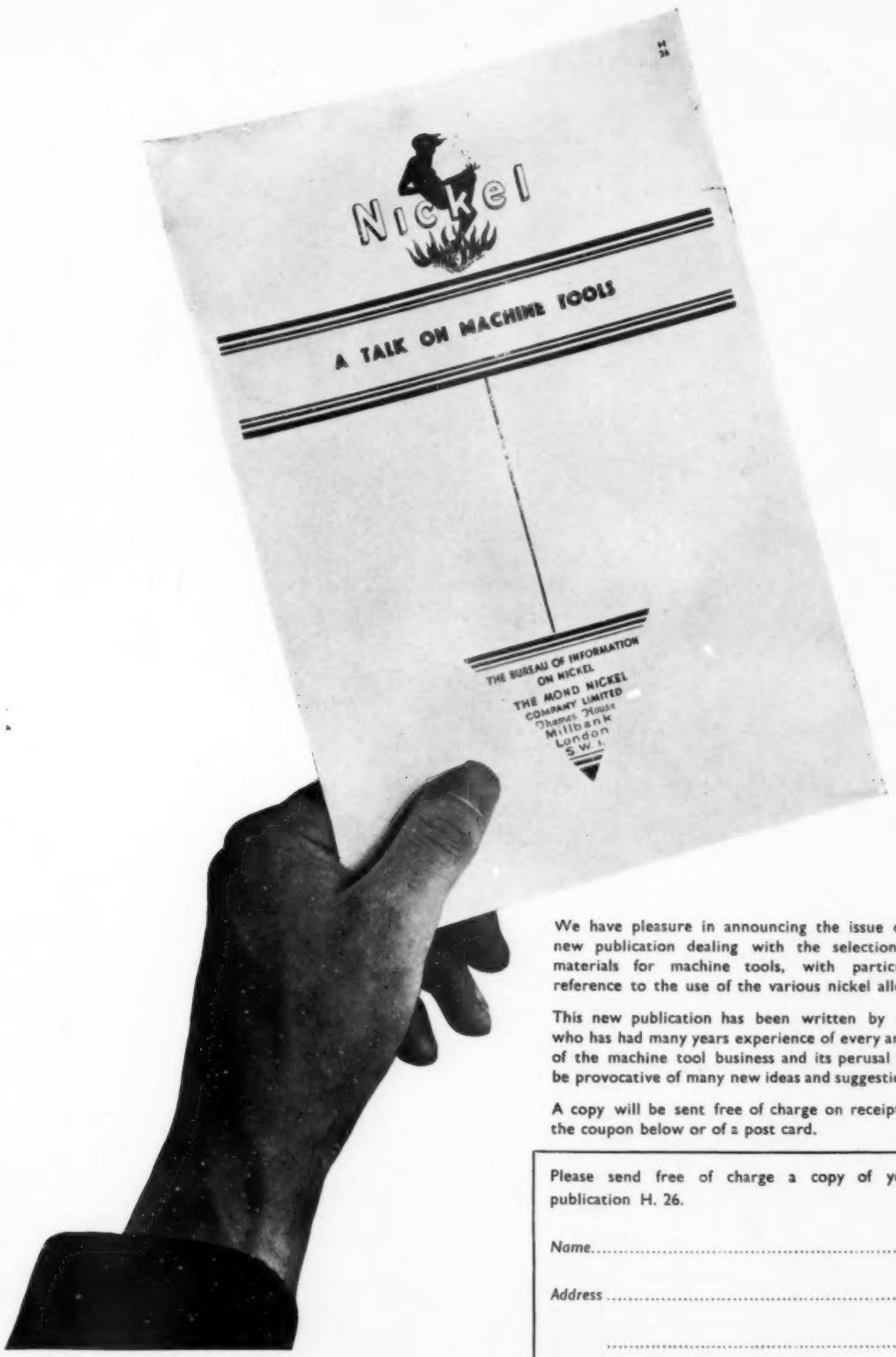

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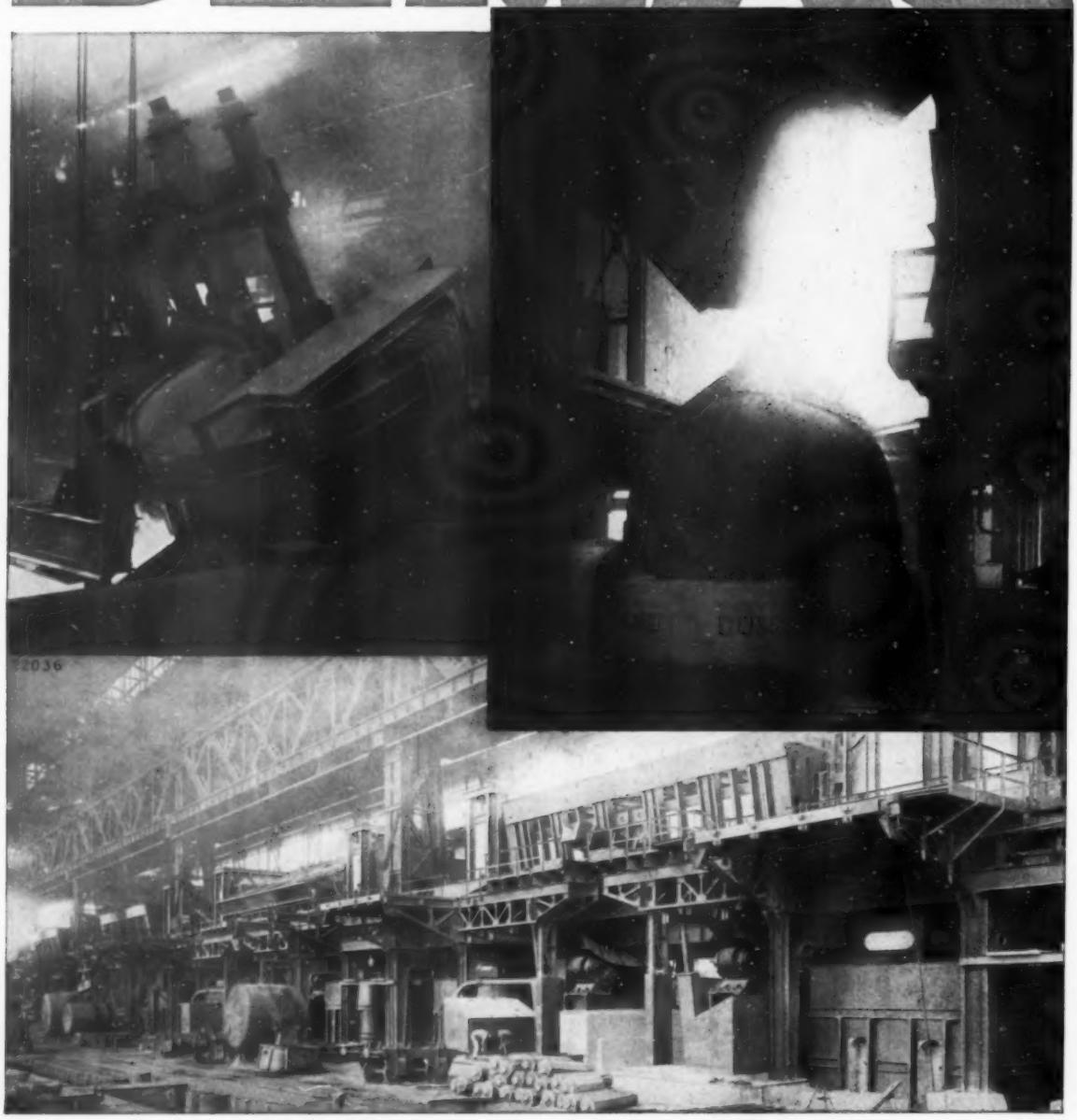

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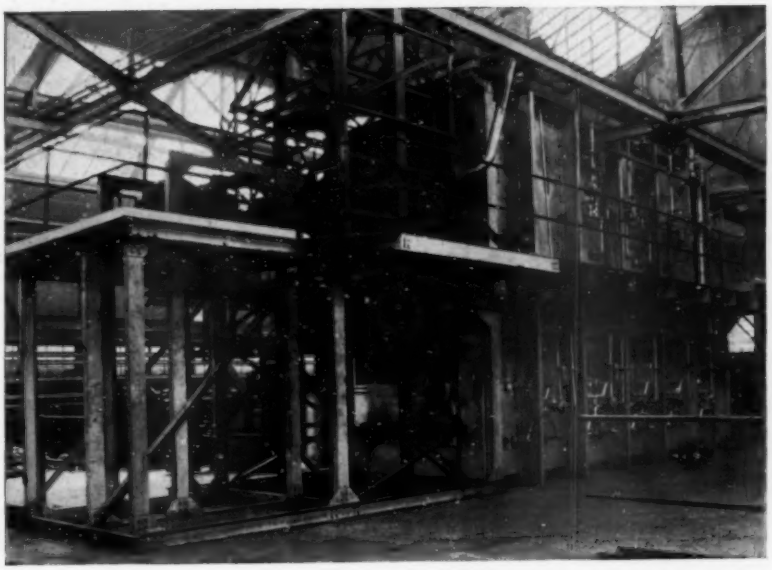

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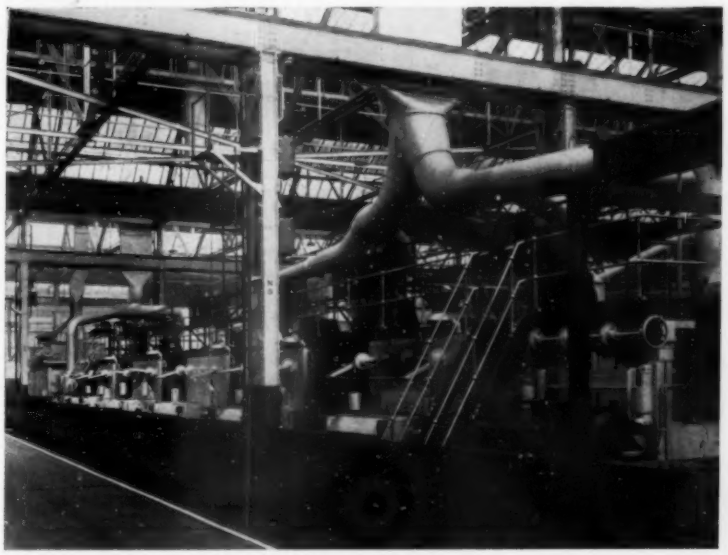

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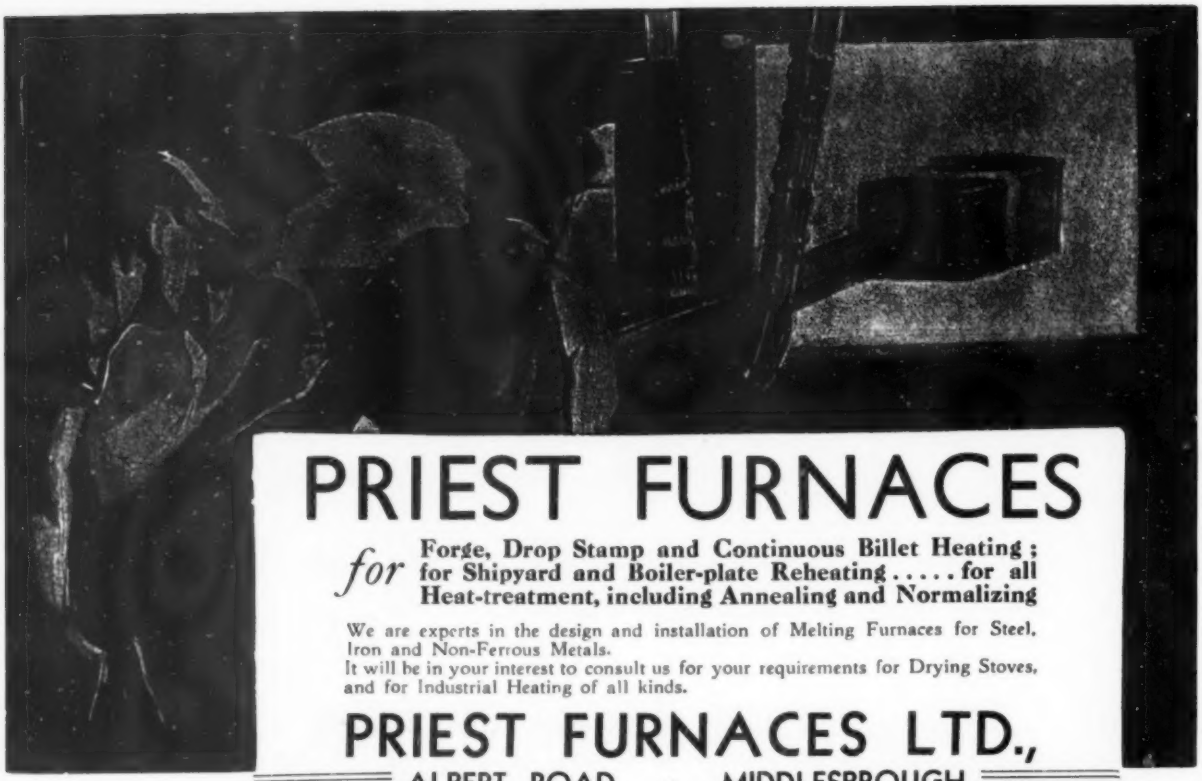

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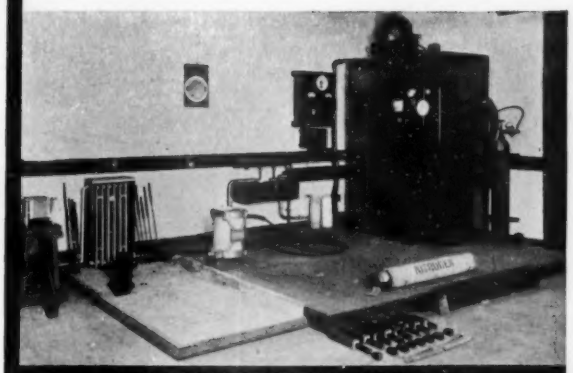

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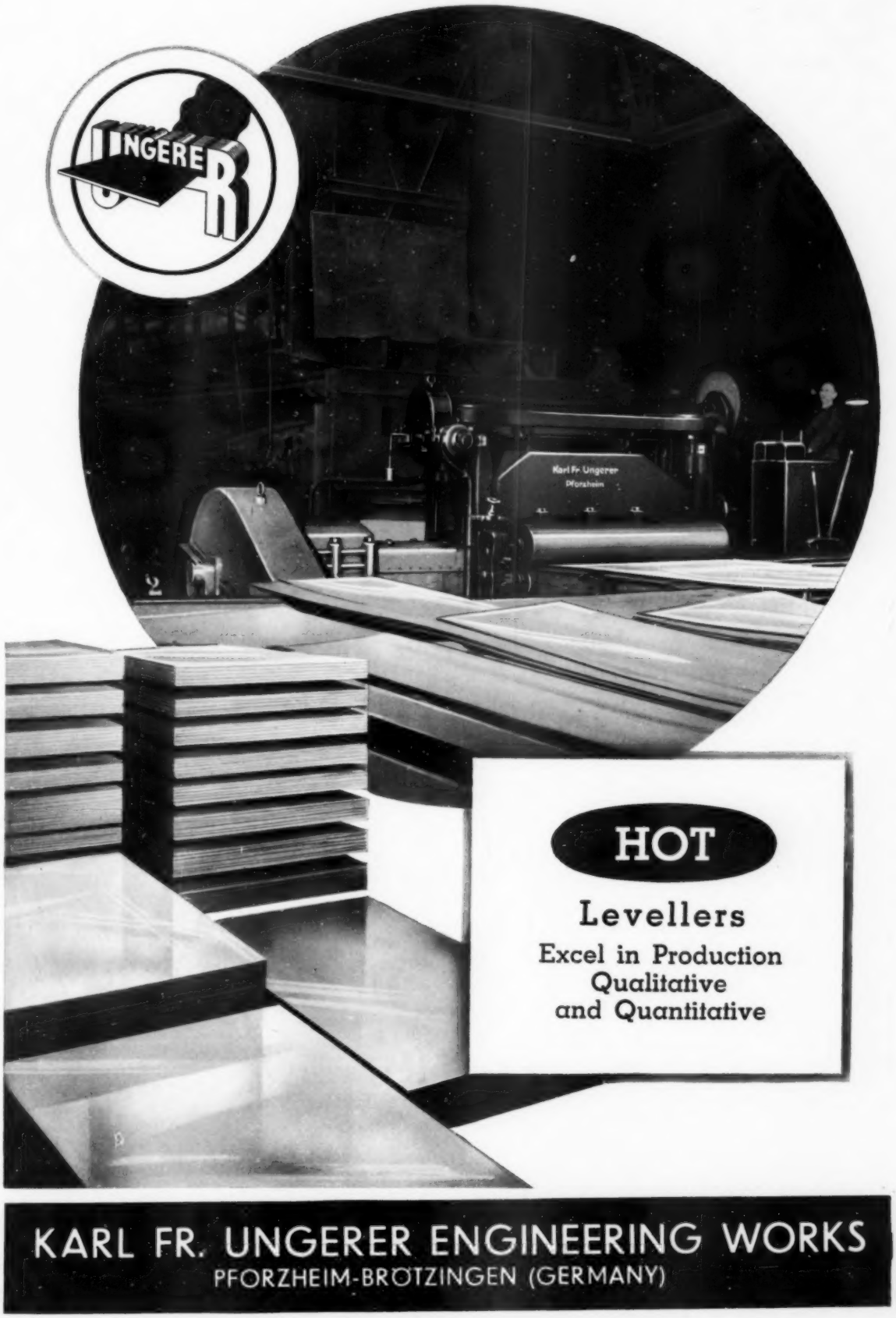
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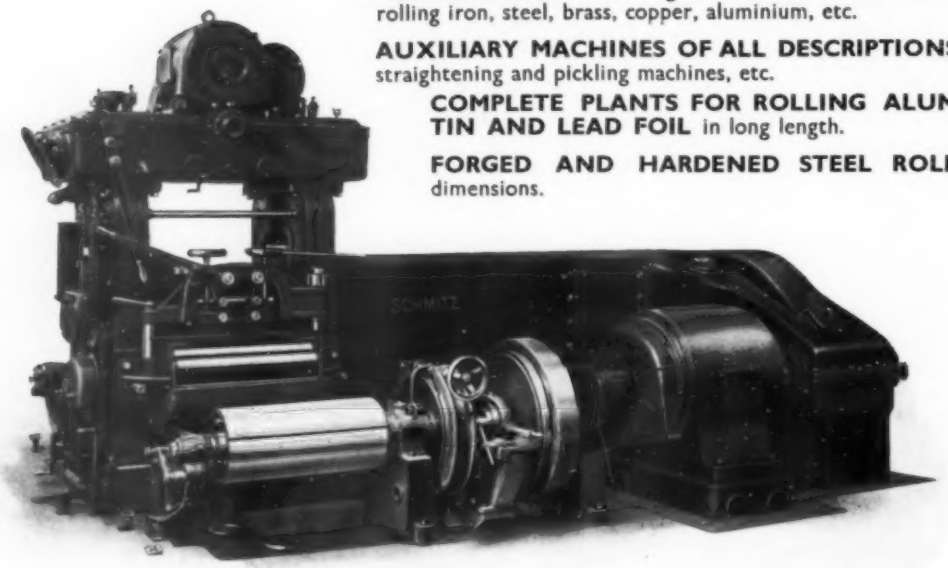

"The furnace illustrated is a 1½-ton Heroult unit, operating with Acheson Graphite Electrodes, in the Works of The National Steel Foundry (1914) Ltd., Leven, through whose kindness this illustration is possible."

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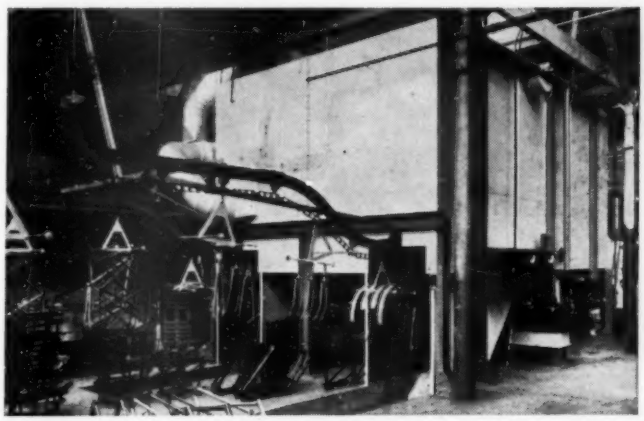
One of the most important operations in the production of a cycle is that of enamelling. For this operation the Raleigh Company use seven gas-fired conveyor ovens. The use of town gas for enamelling ovens is spreading as it has many very important advantages.

The first advantage is its reliability. The gas supply never fails. It is always there in almost limitless quantities at a fixed price. The second advantage is that with a clean fuel like town gas a direct-fired air heater can be used in most cases where an indirect type would have to be used otherwise. Not only does this save fuel, but it simplifies and cheapens the maintenance of the oven, for air heater elements are made of expensive material and have to be replaced regularly.

No fuel can be so easily and accurately controlled as town gas. Oven temperatures can be accurately controlled with the simplest thermostats. The required oven conditions can be more readily obtained with town gas than with any other fuel. Another advantage is the saving in space and labour, for gas requires no storage or handling and calls for less cleaning work and supervision.



Gas-fired conveyor enamelling oven for coloured finishes.

The Raleigh oven described

Cycle frames at the Raleigh works are enamelled in black and also various colours. These two groups are dealt with quite separately.

The standard black finished models are stoved in conveyor ovens measuring 56 ft. long by 9 ft. 6 in. wide by 5 ft. 6 in. high inside. One of these ovens is illustrated here.

At the inlet end of each oven is a tiled dipping room. The parts undergo a three coat process and, as the average capacity of the plant is 10,000 complete cycles per week, some idea can be obtained of the immense number of parts treated.

Each oven is heated by an automatically controlled direct gas-fired air heater and is provided with a recirculating system.

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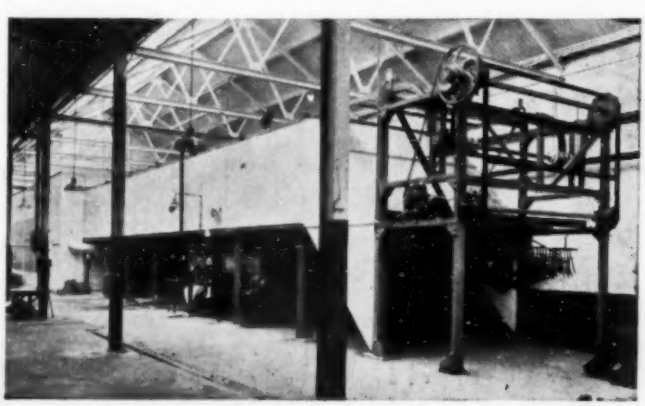
Colour finishes are dealt with in an oven measuring 25 ft. by 12 ft. by 9 ft., also illustrated here. In this oven the entry and exit of the conveyor chain are both at the same end, the chain making four passes up and down the oven chamber during one hour—the time of stoving.

Small parts are dealt with in a similar oven. These number up to 650,000 a week.



Gas-fired conveyor enamelling oven for black cycle parts.

The question of cost

Estimating the comparative costs of fuels is no easy matter. It is entirely misleading to consider the fuel costs alone as the fuel influences so many other costs, all of which vary with circumstances. Taking all in all, however, it is now being widely realised that the use of town gas is an economy. Its saving in labour, space and furnace maintenance more than compensates for any extra cost of the fuel there might be.

All needing expert advice on gas equipment should write to The British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1, who will put the inquirer in touch with the body best equipped to assist him.

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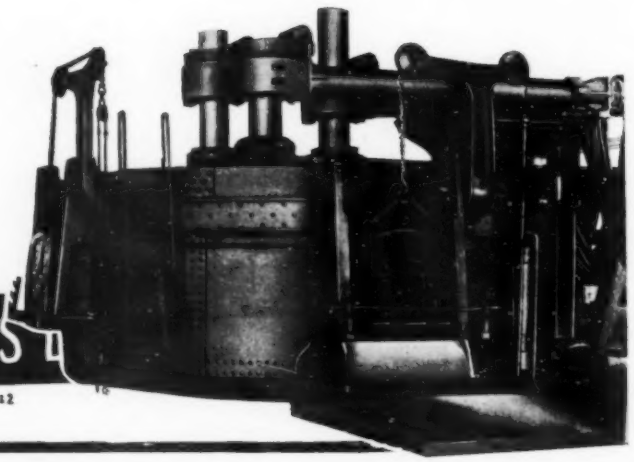

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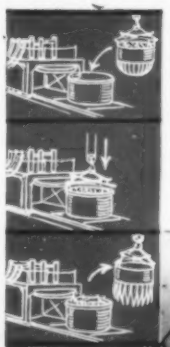

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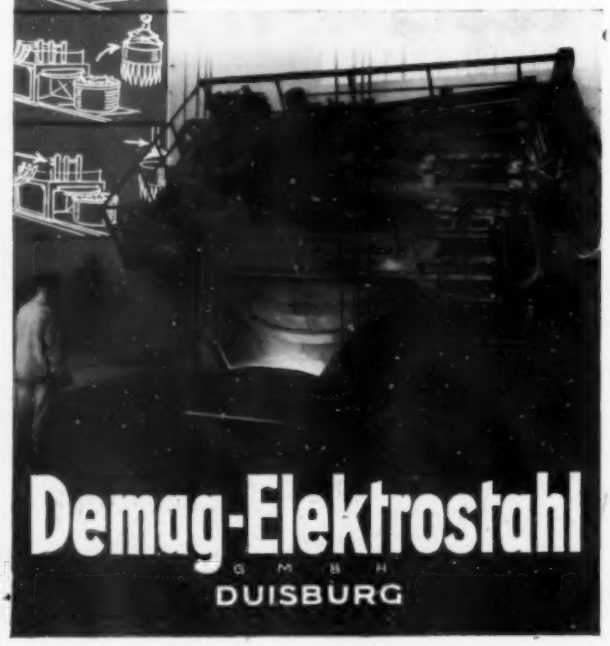
Further particulars may be had on application to address below.



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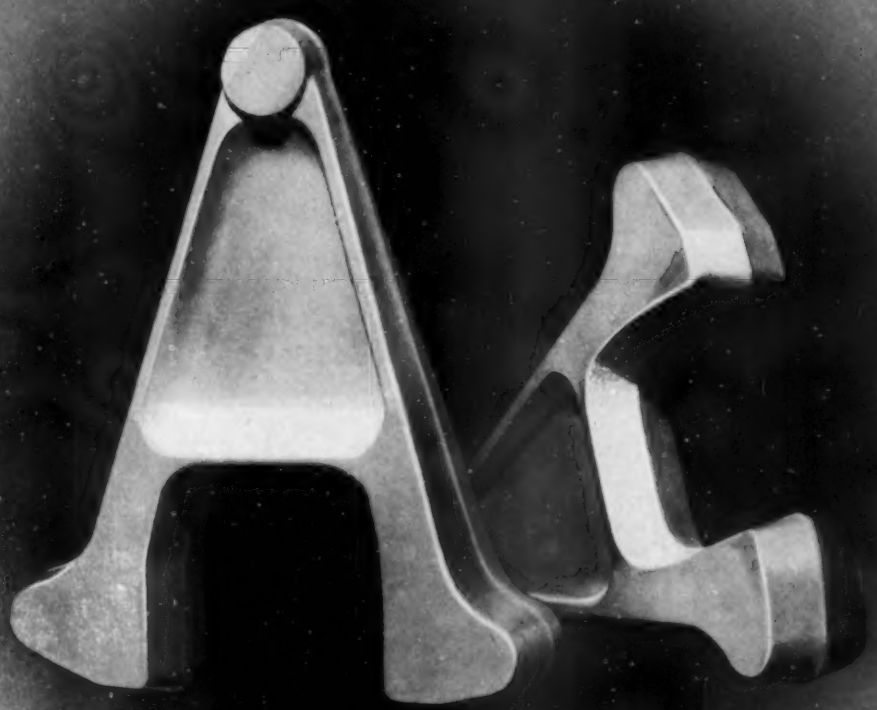

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PRINCIPAL CONTENTS IN THIS ISSUE:

	Page
Rolling Mill Machinery Manufacture .. *In this article brief reference is made to the part played by W. H. A. Robertson and Co., Ltd., in the progress of rolling-mill manufacture, especially in the design and construction of cold-rolling mill machinery, and to the recent extension of their Bedford works to cope with the demands for their products.*	1–4
Research and the Foundry	5
Developments in Tube Manufacture ..	6
Forthcoming Meetings	6
Chromium-Manganese Steels as Heat-Resisting Steels. By J. H. G. Monypenny F.Inst.P. .. .. .. *The structural characteristics of chromium-mangancse steels are discussed, more particularly as affected by prolonged heating at high temperatures. Recent important investigations on the subject are also discussed.*	7–12
Resistance Welding Progress..	12
High-Duty Brasses and Bronzes available to the Engineer; Their Properties and Applications. High Duty Bronzes. By F. Hudson .. *The properties and applications of some modern high-duty alloys were discussed in a previous issue under the grouping of high-duty brasses, and in this article the author deals with those alloys containing an appreciable quantity of tin, which constitute the true bronzes.*	13–16
Molybdenum in Tool Steels. By W. F. Chubb .. .. *The fundamental principles upon which the use of molybdenum in tool steels is based are briefly described, and details are given of the properties obtainable in steels employed for these purposes. Experiences in quantity production, both in this country and America have been incorporated together with the results of some original researches.*	17–18
A New Industrial Map of the U.S.S.R. By a Special Correspondent .. .. *The widespread industrialisation of the formerly backward areas, rich in raw materials and power resources, and the economic development of the various regions are the main features contributing to the new industrial map. In this article the development is reviewed.*	19–20
Mechanical Properties of Copper-Tin Alloys at Elevated Temperatures.. *The results of an investigation to establish a reliable means of comparison between four standard tin bronzes and other bronzes are discussed.*	21–22
Hiduminium RR77 .. .. *A new alloy in the Hiduminium series, developed after long research, possesses unique properties. Not only does it possess high strength, but it has excellent corrosion resistance, ductility, fatigue resistance, electrical and thermal conductivity.*	22
Reviews of Current Literature .. .. *Arc-Welding Handbook. Transactions A.I.M.E.* (1937). Vol. 124.	23–24
The Lincoln Arc-Welding Foundation..	24
Controlled Atmosphere Annealing. By E. C. J. Marsh, B.Sc., A.I.C., M.Inst. Met., and E. Mills, M.Inst. Met. .. *Expensive cleaning treatment can now be obviated by annealing metals in a controlled atmosphere, and this article is mainly concerned with practical difficulties which arise in operating a furnace of this nature.*	25–27
Correspondence .. .. *An aid to more efficient Heat-treatment.*	28
Die Casting .. .. *The use of die castings is discussed, production method described, and particular attention directed to the choice of suitable alloys.*	29–30
Solvent Degreasing .. .. *The processes for the removal of oil and grease from metal articles prior to electro-plating.*	30
Metal-Sprayed Surfaces in Relation to Lubrication .. .. *Sprayed metal is claimed to provide better bearing surfaces and experiments have shown that these surfaces working against each other will carry a higher seizure load and possess a lower coefficient of friction than when one of the metals is produced normally.*	31
New Roughing Mill	32
Electro-Magnetic Slip Couplings, for Use with Geared Diesel Engines	32
Business Notes and News	33
Metal Prices	34

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NOVEMBER, 1937. VOL. XVII. No. 97.

Rolling Mill Machinery Manufacture

Developments at the Works of Messrs. W. H. A. Robertson & Co., Ltd.

Many important advances have been made in the design and construction of rolling mill machinery in recent years. Demands for increased rolling speeds have had far-reaching effects. In this article brief reference is made to the part played by W. H. A. Robertson and Co., Ltd., in this progress, especially in the design and construction of cold-rolling mill machinery, and to the recent extension of their Bedford works to cope with the demands for their products.

IT is logical to assume that the increased production now being experienced in the ferrous and non-ferrous metal industries is considerably influenced by the improved facilities resulting from technical progress. Keen competition during the years of depression cause new conditions to arise and force even the most established firms to realise the necessity of preparing to meet them more efficiently. The general trend is towards the use of improved materials and superior technique in manufacturing processes; advantage is also taken of the best research facilities available, the main object being to effect all possible economy in production, while maintaining or increasing the quality of the product. The need for improved materials has led to the invention or development of a wide range of metals and alloys, possessing special properties to meet the ever-increasing demands of the engineer, and there has been important advances in the design and manufacture of machinery to produce the many forms in which these metals and alloys are now available.

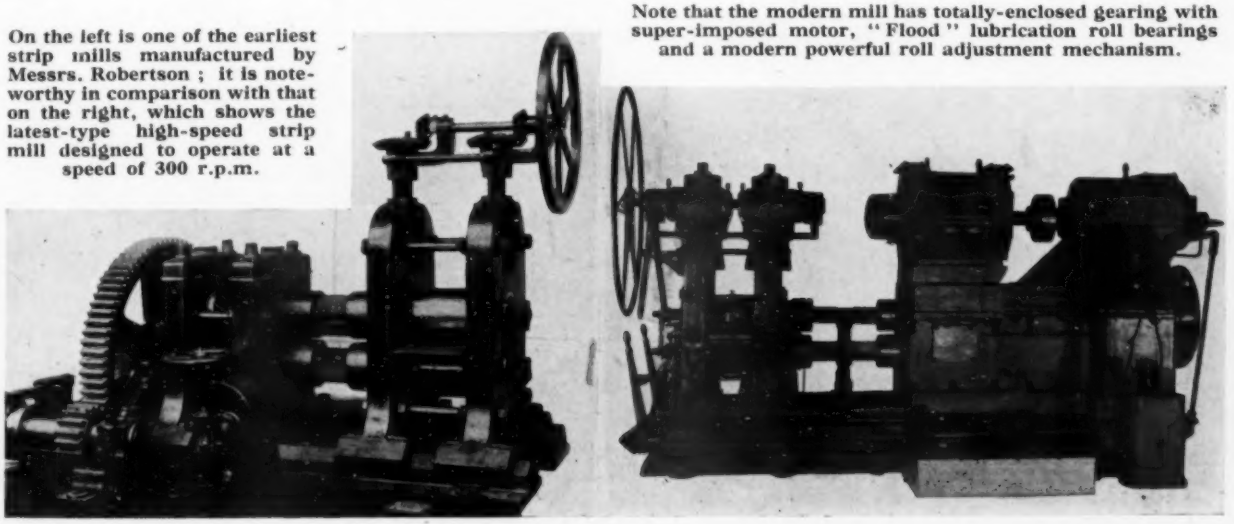
Probably the most important machinery to influence the character and quality of the finished metal or alloy is the rolling mill, a type of machinery which is not by any means modern in principle, but which, in design and construction, has made remarkable advances in the last thirty or forty years. While many firms have contributed to this period of progress, not the least important in this respect is the firm of W. H. A. Robertson and Co., Ltd., of Bedford, which commenced operations early in this period. Concentrating on the design of rolling mills and auxiliary machinery in a small way, and paying particular attention to quality in production, this company has earned a reputation which has resulted in steady growth of the works to meet increasing needs and recent extensions carried out to provide facilities for greatly increased production is in keeping with the progressive spirit shown since its inception.

The small shop in which the firm commenced its operations is still intact and in use, but for many years its size has been dwarfed by several shops which have been added from time to time and with the recent extensions the works now cover an area of about 65,000 sq. ft. Despite an increase in area of about 50 per cent. by the creation of the new buildings, the space and new machinery installed are fully occupied and the directors of the company are entitled to much credit for the energetic manner in which the business has and is being continually developed and increased. Considerable acumen and foresight has been displayed, and many far-reaching developments have been contributed to the development of modern rolling mill plants.

Mention may be made of the introduction of the high-speed cold-rolling mill into this country and most of the important European countries, for which Messrs. W. H. A. Robertson are undoubtedly responsible; prior to this, few

On the left is one of the earliest strip mills manufactured by Messrs. Robertson; it is noteworthy in comparison with that on the right, which shows the latest-type high-speed strip mill designed to operate at a speed of 300 r.p.m.

Note that the modern mill has totally-enclosed gearing with super-imposed motor, "Flood" lubrication roll bearings and a modern powerful roll adjustment mechanism.



Part of heavy-machinery bay for the construction of rolling mills with erection section in the back ground.

strip mills for steel or non-ferrous metal were operating at speeds exceeding 80/90 ft. per min., whereas such mills are now in successful operation at ten times that speed. In fact, with progress proceeding at the present rate, rolling speeds now considered to be impossible will become commercially practicable in the near future, and this firm is apparently fully alive to future possibilities in this respect.

The Robertson high-speed two-high mills have now an international reputation, and their success is only made possible by the invention of the " Flood " lubrication roll bearings, which eliminate hot bearings and reduce power consumption per ton of metal rolled well below that of the best slow-speed mill of the older type. The development of these bearings, in their present perfected design, is an outstanding achievement, as it can be claimed that these are the first and most successful practical roll bearings provided with a continuous " Flood " cool oil circulation.

The firm can also claim to be the first designers and builders of backed-up roll mills, of the four-high type, in this country, and a complete range of four-high mills, from the smallest to the largest, are now being regularly supplied to important firms in this country and abroad. These four-high mills for strip in all metals and alloys are normally working at speeds up to 400 f.p.m., and are stated to give a greater output than any other similar mill of equal roll dimensions.

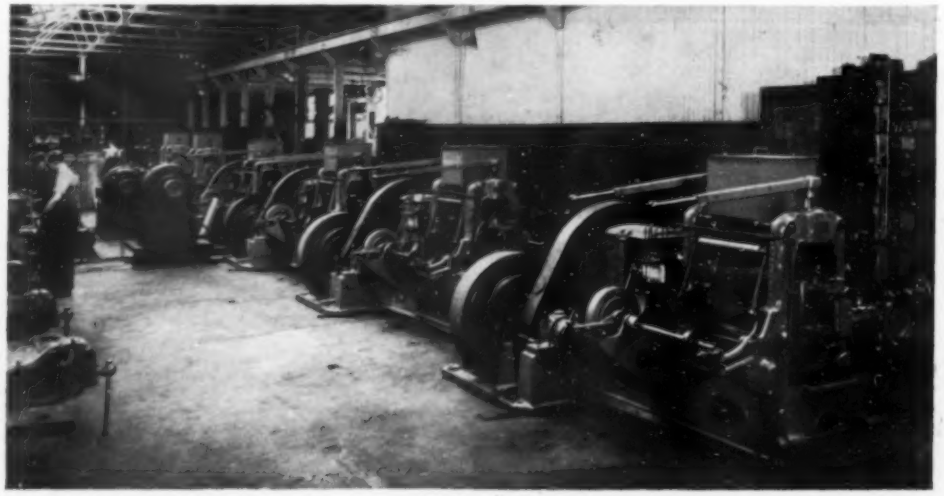
In connection with high-speed rolling, it is believed that Messrs. Robertson have built and installed mills of a special design which are the *fastest in Europe*, having a maximum speed of 1,000 f.p.m. These mills have many unique features, and are equipped with a patented system of hydraulic roll pressure control.

Wide strip mills of the reversing type, with automatic electric control of coiler tension, are also under construction at the present time, together with several trains of tandem continuous four-high mills for steel strip.

Owing to association with well-known American firms, such as the Torrington Manufacturing Co., the Hallden Machine Co., and the John Robertson Co., the Bedford firm are building, in increasing numbers, valuable auxiliary machines, such as " Tormanco " wire flattening and edging mills, section straightening machines, automatic coilers, slab millers, etc., and the famous Hallden automatic flattening and cutting-off machines. A complete range of rotary shears or gang-slitting machines, swaging machines, and multiple roll strip-forming machines, are fulfilling an increasing demand.

For wire-drawing machinery, an entirely new series of multiple die high-speed machines, for both steel and non-ferrous wire, have already gained a unique and high reputation ; a special organisation under able management has been built up during recent years, and a large number of machines are under construction. Further new and improved designs have just been put on the market, which embody features which cannot be obtained from competitive machines.

Limitations of space prevent further reference to improvements made by this firm in developing the capacity of machines for high production economically and at low maintenance costs. Suffice to say, that improvements, many of which are patented, have been constantly developed



A complete installation comprising six high-speed aluminium foil rolling mills for foil 20 in. wide. Note that the two mills shown in the background are connected to motors for test purposes.

Part of fitting shop and erection bay for small- and medium-sized mills and auxiliary machinery.

since the inception of the firm, and to-day the range of machines manufactured is considerable and covers a varied field. Not only is the company concerned with the production of rolling mills, for both the ferrous and non-ferrous metals industries, with their wide range of requirements, but also, it will be noted, with the design and construction of many important auxiliary machines, such as straightening, shearing, and gang-slitting machines of various types and sizes, while the production of wire-drawing machinery is a further speciality for which the company has earned an enviable reputation.

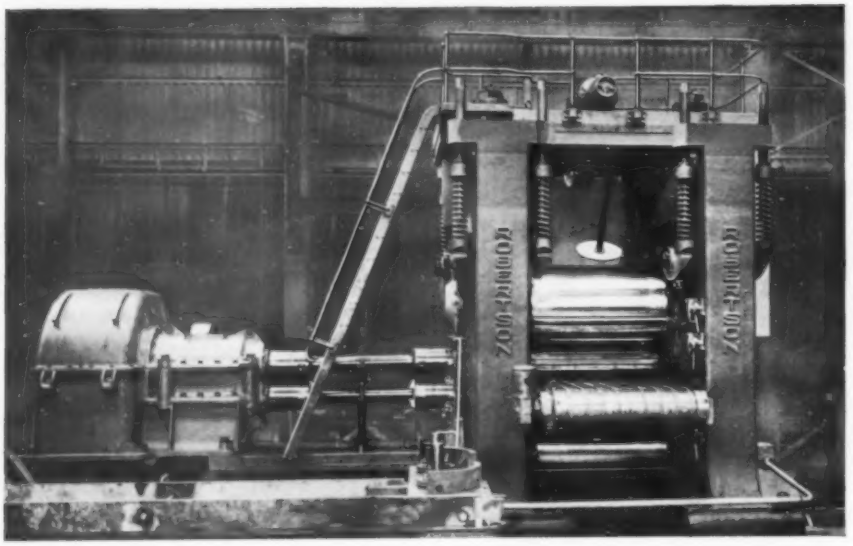
The design and construction of serviceable rolling mills has long been recognised as the work of specialists. So many factors are involved in their design that success is only possible after long experience and careful study of rolling operations. Broadly speaking, the rolling of metals is divided into two main operations—hot- and cold-rolling; and for each type a very wide range of mills has been developed to suit the metal to be rolled and the particular shapes and sizes desired. One of the main objects of the hot-rolling process is to destroy the "as-cast" structure; in this operation ingots are reduced to blooms or slabs in a blooming mill preparatory to entering a roughing stand, where the rolled bar is further reduced and shaped to enter the final or finishing mill.

In view of the care necessary to obtain the required properties in the finished products, together with the great accuracy and uniformity of dimensions now demanded, the modern cold-rolling mill is an intricate piece of mechanism requiring high driving power and possessing complex auxiliary gear. It is, in fact, a precision machine by comparison with those in use thirty or forty years ago, and different classes of work are now given special consideration in the design of a mill, because of the widely varying treatment in the method of rolling specific materials.

To-day cold-rolling mills are built in various sizes and designs, depending on requirements, the preferences of mill managers, and engineering features, such as have been mentioned in connection with Messrs. W. H. A. Robertson and Co., Ltd., as developed by manufacturers of special machinery. Details of design and construction for a given type of mill vary considerably among the different builders. Many factors may, and do, influence mill managers in the choice of mills for cold-rolling. Some of these include the following: The class of work to be done; the size of material to be processed; capacity required; gauge tolerances to be met; layout of the plant and available space; whether tonnage in a few sizes or small lots of many sizes are to be rolled; and whether mills are to supplement existing machinery in an old plant or are to be installed in a new works. Speed of rolling, also, is obviously an important consideration.

Generally speaking, all-purpose mills are best adapted to the requirements of small plants, unless only special classes of products are to be rolled, but in large plants various types of mills may be installed to advantage for processing different classes of stock. No type of mill is best adapted to all requirements, but the ordinary two-high non-reversing mill, equipped with rolls of moderate face length, is suitable for a variety of rolling purposes. In addition

Part of machine shop or the mass-production of small parts.



A four-high sheet mill for stainless-steel sheets up to 4 ft. wide. It will be noted that the erection of this mill is almost completed. It is a massive structure weighing over 210 tons; each of the steel housings weighs about 40 tons. This mill is built to the order of one of the largest Sheffield steel firms.

to the two-high mills which include sheet, coil strip, and continuous mills, three-high, four-high, and cluster mills may be used.

During comparatively recent years this Bedford firm has contributed to the advances made in the design and construction of cold-rolling mills to meet the demands for increased rolling speeds. Housing, coupling and drive structures are now more rigid, better fitted, and made of stronger materials. Precision machines are installed to ensure the necessary accuracy in building the modern high-speed mill.

Satisfactory results with the four-high mills came with the application of roller bearings in place of the usual neck brasses. These bearings are also used on two-high mills and other types, with important savings in power consumption and other advantages. More efficient methods for lubricating roll necks have more recently been developed and the use of automatic lubrication is now regular practice; the firm's system of "Flood" lubrication and roll-bearing design being major contributions to these developments and an important advance for both two-high and supported roll mills. In practice, these "Flood" lubrication bearings have been especially successful for support rolls in backed-up mills.

Demands for better surface finish and closer gauge tolerance of sheet and strip products have had a marked influence on methods and details of mill construction. These requirements have been the subject of close study, and considerable attention is directed to the close fitting of reduction units and couplings to prevent back-lash and chattering, which have adverse effects on the material being rolled. Special precautions have been taken to eliminate vibration and noise caused by inaccurate fitting pinions, faulty alignment, incorrect tolerances, poor lubrication, and unsupported spindles connecting pinions and rolls or two sets of rolls. Pinions, as well as gears in reduction units have machine-cut teeth to ensure accuracy. Spindles are suitably supported to carry the weight and absorb shocks.

The gradual increase in the size of these works has not only enabled this firm to meet the growing demand for efficient mills, but it has facilitated the building of larger mills to supply the need for wider sheet and strip in both ferrous and non-ferrous metals and alloys, and in the new extension large sheet mills are in course of erection for stainless steel.

The works are divided into a large number of departments, each forming a link in the chain, making for progressive means of production. Care has been taken to gauge the capacity of each department, so that the erection of the mills can proceed on a well-ordered plan, thus avoiding congestion in any one department. The offices which house the administrative, organising and drawing-office staffs are situated adjacent to the main entrance. The various rooms are arranged to give ample facilities for intercommunication, so that little time is wasted. They are airy and well-lighted, and consistent with the requirements of a busy works. The drawing office in particular is well lighted, and is adequately equipped to deal with all work undertaken.

In the several bays devoted to the construction of mill machinery a certain amount of sectional planning has been adopted, in which each bay comprises machine fitting and erection sections. In this way the movement of parts is minimised between the machine-shop and the assembling department in a particular bay, and the method has facilitated the installation of equipment in each bay to accommodate a range of products for which it is designed. Overhead travelling cranes are installed of 2 to 40-ton capacity to meet the requirements and possible future developments in the size of mills.

In the period under review there have been important changes in the castings used in the construction of rolling mills, the most important being the greater need for steel and other high-duty materials for castings in place of those formerly made in cast iron. Special facilities are available for the production of the various castings necessary in materials, which are strictly governed by standard specifications, so that they will provide the requisite strength to meet the increased demands of modern mill construction.

A separate section of the works deals with the mass production of small steel and cast-iron parts, such as keys, collars, and handwheels, used in large quantities in various engineering trades. Standard designs have been got out for handwheels, keys, and collars which can be used on all types of machines. Particular attention has been given to the development of a department for producing screwing-dies, in which the machine hardening and testing equipment provides the very latest practice for efficient production of this highly accurate and specialised work. When the writer visited these works this section in particular was working under very high pressure.

Although recent extensions to these works have just been completed and put into service, further pressure on the firm's productive capacity, resulting from growing demands, has necessitated more working space, and arrangements have been made to remove the pattern-shop and pattern storage to a new site, in order that one of the present machine- and erecting-shops can be extended. The writer understands that the steelwork for this extension is already on order, and construction will proceed immediately.

The works are well equipped, and despite the numerous extensions are conveniently arranged for speedy production, and the writer takes this opportunity of thanking the directors of the firm for permission to see the new extensions together with the plant and equipment used in the production of modern cold-rolling mills and accessory machinery.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

Research Scheme for the Foundry

An Appeal

IRON castings play such an important part in many trades and industries, and the opportunities for their increasing importance are so great that the question of quality should have a special significance ; yet, in many respects, the foundry industry is not as progressive as it should be. As a basic industry, it should lead research and development and provide facilities for the intensive exploration of all avenues likely to provide facilities for progress. Much valuable work has been done in this and other countries to restore cast-iron to a place of eminence among structural metals, but, in this country particularly, progress is not as rapid as it might be.

Excellent work has been done by the British Cast Iron Research Association to improve the products of the iron foundry and, considering the facilities at its disposal since its inception in 1921 and its relatively small income, it has done remarkably well. It is probably true that the results of research work carried out have not been as widely applied as is desirable, but many British foundries have made use of the knowledge obtained from these researches, and now produce castings which possess qualities that are not exceeded by the cast-iron products of any other country. No body of this kind, however, can function effectively and efficiently without proper equipment and accommodation. It is gratifying, therefore, that the Council, after some months' deliberation, has decided that the time has arrived to ask the industry to put the Association on a satisfactory footing,

The decision of the Council was made in an address by its President, the Rt. Hon. The Earl of Dudley, at the recent annual meeting, in which he stated that the Association does not possess any resources from which proper provision can be made. Indeed, all the provision that could be made out of income has been made, and the reserves do not cover more than the cost of three months' working. The Council feels that during the good time now being experienced is the most suitable to ensure the future prosperity of the industry—for which research expenditure is an insurance premium—by giving the Association proper equipment and accommodation.

The Council is justified in feeling that the least that can be done to ensure a contented, permanent staff, the growing experience of which, of course, becomes increasingly valuable, is to provide reasonable accommodation, free from noise and external distraction, and with the equipment and apparatus essential to the conduct of their work. With respect to apparatus and equipment, they should be not merely adequate in variety, but the best of their kind. It is necessary to maintain the prestige of this country, and, indeed, of the Empire, in this field of work, and the industry should not view with complacency the better provision of countries with lesser responsibilities and smaller resources.

According to the Annual Report for the last year's working, the income of the Association, between £16,000 and £17,000, is the highest recorded in its history, and implies a correspondingly higher degree of activity, but the scheme envisaged by the Council will cost £30,000. By arrangement with the Department of Scientific and Industrial Research, contributions to this scheme will be treated as grant-earning. As is fairly well known, the scheme under which the Association is at present working with the Department of Scientific and Industrial Research permits more grants to be earned than is possible with the present income, and at the middle of 1939 a new five-year plan opens. If members of the Association are prepared to furnish a sum roughly equivalent to double their normal annual subscription, preferably, but not necessarily, spread over a period of years, the aim in view will be accomplished, for this should yield £15,000.

To those firms who have not yet been persuaded to support the Association, Lord Dudley stressed the undoubted benefit of its work to the industry as a whole, and hence, to all firms that are in it, and expressed the hope that all non-member firms would soon conclude that they can scarcely fail to benefit from such an annual expenditure, a conclusion which is supported by recent remarks of the Prime Minister, in referring to the growth and importance of the research association movement, and to the necessity for increasing expenditure in this direction. The appeal is extended to the user of the products of the foundry, whose active interest is more difficult to enlist, principally those engineering and other works not having foundries, and buying their casting requirements from outside sources. The invitation to support this scheme is extended to all who are concerned with the industry.

It may be profitable to consider briefly what justification the Association has for meriting the confidence of those connected with the industry. Even to summarise all the research work done and the developments in practice resulting, however, would occupy too much space here, but a reference to the successive reports disclose fundamental work that has been instrumental in raising the status of the iron foundryman and facilitating his work in meeting more exacting demands.

Apart from the steady progress disclosed by these reports, there are the services of the staff set aside for dealing with technical and practical inquiries from members. These inquiries often involve analytical and testing work, sometimes minor investigations and not infrequently, visits to members' works. This forms a direct return for the subscription income. In addition, the research programme is continuously carried forward, the results of which are reported to members, and there is no doubt that the results have had a pronounced influence upon the development of the art and science of founding in this country.

It is difficult to assess the direct financial value of the results of research, but there is one case in which such an estimate is practicable. It is suggested in the Report that the installations of the balanced-blast cupola, now nearly 180 in number, yield on a conservative estimate, fuel savings in this country of the order of £25,000, roughly three times as much as the industry furnishes in each year by way of subscriptions. It is also stated that something like 20 to 25 per cent. of the cast-iron melted in Great Britain is melted in this type of furnace, a result which, after seven years' development, is very striking.

The scheme envisaged by the Council is a very worthy one, though probably too modest, but financial assistance is necessary, so may we, therefore, ask readers who would like to contribute to the scheme, or to become subscribing members of the Association, to communicate with the Secretary, 21-23, St. Paul's Square, Birmingham 3.

Extensive Developments in Seamless Tubes

EVENTS in the seamless tube trade have followed quickly on the decision to instal a new steel tube manufactory at Jarrow-on-Tyne, a scheme initiated for the relief of a destressed area, by Sir John Jarris, M.P., and assisted by Tubes Investments of Birmingham. The site of this new layout is adjacent to that of Palmers Shipbuilding Co. Ltd., and it is of interest to the trade generally to recall that a non-ferrous factory—The Tyneside Brass and Copper Tube Works, more or less flourished in the district up to about 1907, the bulk of that plant passing into the hands of the demolishers a year or so later, this in accordance with the decision of the syndicates of other Tube makers who purchased the whole of the operative plant and tools. A large number of the employees found occupations with the then Leeds Copper Works Ltd., which was ultimately reconstructed and organised by the present The Yorkshire Copper Works Ltd.. Leeds, Yorkshire.

In recent months Imperial Chemical Industries Ltd. have decided to manufacture tubes of copper and its alloys on Clydeside, and a site chosen for the new works is at North Hillingdon, between Glasgow and Paisley. Another development is the decision of the Yorkshire Copper Works Ltd., to lay down an extensive additional and similar plant at Barr Head, on the Clyde, which will be devoted to making non-ferrous tubes of all classes and to any desired specification. With a most modern and up-to-date plant at the Leeds works, speculation is rife in the trade as to whether the material as prepared in the initial processes will be sent to the Scotch works for finishing or whether new casting, piercing, rolling and extension machinery will be included in the new development.

One factor which has had influence in these additions to the non-ferrous tube trade was the introduction of the new Standard Specification (British) governing the domestic systems of water supply and heating, especially as applied to hotels, offices, houses, residences, housing schemes, etc., the demand for tubes for these purposes having assumed greatness in quantity and quality. It is obvious that the Clyde as a shipbuilding centre provides a ready-made, market for non-ferrous tubes of condenser, steam boiler, lubricating and the like types.

The Yorkshire Copper Works Ltd., in addition to the modern factory at Leeds, also specialise in all kinds of fittings, having made extensions at the Stourton works for stamping these articles which are also in great demand for completion of the domestic services referred to. A well-known tube company in the Black Country district, near Birmingham, are also extending their plant to cover the smaller diameters of copper tubes, and it is understood that this will be actually producing in the course of a few weeks. The non-ferrous tube trade is and has been for some considerable time experiencing a tremendous boom, indicative of which is the fact that many manufacturers in the Birmingham area have for some time past been working double shift, and even under this pressure have been unable to cope satisfactorily with the great demand for tubes for all purposes. It is a gratifying tribute to British engineering development that of late years the "Serck" extension press for bars, rods and tubes has competed successfully with German competition, and recent instalments of this plant have been made by P. H. Mintz, West Bromwich, and Hudson and Wright Ltd., Birmingham. This type of press is manufactured solely by Messrs. Fielding and Platt Ltd., Gloucester, and this firm have also supplied similar plant to Norway and Sweden.

New Sheet Mill

The new sheet mill for stainless steel which is to be installed at the Stocksbridge works of Messrs. Samuel Fox and Co. Ltd. will be the largest of its kind in this country and will be equipped with four British Timken bearings. Each of these bearings weighs over 8,000 lb., and the capacity will be equal to that of the largest bearing in the world.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Nov. 19. "The Mechanics of Flame and Air Jets," by R. F. Davis, B.Sc.

Dec. 10. "Metal Fractures and What They Tell Us," by G. A. Hankins, D.Sc.

IRON AND STEEL INSTITUTE.

Nov. 23. "The Mechanism of Nitride-Hardening," by M. S. Fisher and Z. Shaw; "Further Experiments on the Nitrogen-Hardening of High-Chromium and Austenitic Steels," by B. Jones; and "Some Alloys for Use at High Temperatures." Part IV. —"The Constitution of the Alloys of Nickel, Chromium and Iron," by C. H. M. Jenkins, E. H. Bucknall, C. R. Austin and G. A. Mellor. At the Metallurgical Club, 198, West Street, Sheffield.

ROYAL AERONAUTICAL SOCIETY.

Dec. 11. Works Visit to High Duty Alloys Ltd., Slough.

INSTITUTION OF METALS.

BIRMINGHAM SECTION.

Dec. 2. Open Discussion—"Bright Annealing."

„ 14. "The Expert Use of the Microscope," by Harold Wrighton, D.Sc.

LONDON SECTION.

Dec. 9. "Magnesium Casting Alloys," by A. J. Murphy, M.Sc.

SCOTTISH SECTION.

Dec. 14. "Modern Non-Ferrous Castings and their Engineering Interest," by F. Hudson.

SWANSEA SECTION.

Dec. 14. "Hot-Dipped and Electrodeposited Tin Coatings," by D. J. Macnaughton.

MANCHESTER METALLURGICAL SOCIETY.

Nov. 17. "Modern Views of Cast Iron," by A. L. Norbury, D.Sc.

Dec. 1. "Non-Ferrous Welding," by H. W. G. Hignett, B.Sc.

INSTITUTE OF BRITISH FOUNDRYMEN.

BIRMINGHAM BRANCH.

Dec. 3. "The Trend of Research on Foundry Matters," by G. L. Bailey, M.Sc.

EAST MIDLANDS BRANCH.

Nov. 20. "Examples of Practical Moulding," by F. G. Butters.

Dec. 11. "Discussion on Gating and Feeding of Castings," introduced by H. J. Beck, T. Goodwin, and F. Dunleavy. At Loughborough.

LANCASHIRE BRANCH.

Dec. 1. "Modern Ferrous Foundry Practice," by First Prize Winner of "Coronation" Competition.

BURNLEY SECTION.

Dec. 7. "Gravity Die Casting of Aluminium Alloys," by A. Palmer.

LONDON BRANCH.

Dec. 9. "Magnesium Casting Alloys," by A. J. Murphy, M.Sc. Joint Meeting with the Institute of Metals.

EAST ANGLIAN SECTION.

Nov. 18. "Some Impressions of Modern Iron Foundry Practice in the U.S.A." by A. B. Everest, Ph.D., B.Sc.

SCOTTISH BRANCH.

Dec. 11. "Refining Steel in a High Frequency Furnace," by Victor Stobie, M.I.E.E.
Annual Dinner, Grosvenor Restaurant, 6 p.m.

SHEFFIELD BRANCH.

Dec. 2. "Some Notes on the Properties of Chilled Shot and Grit as Used for Shot Blasting," by J. E. Hurst and J. H. D. Bradshaw.

WALES AND MONMOUTH BRANCH.

Nov. 20. Cinematograph Lecture by S. E. Dawson, F.I.C.

BRISTOL SECTION.

Dec. 11. "Testing of Foundry Sands," by N. D. Ridsdale.

WEST RIDING OF YORKSHIRE BRANCH.

Dec. 11. "The Production of Certain Iron Castings," by J. Roxburgh.

Chromium-Manganese Steels as Heat-Resisting Steels

By J. H. G. MONYPENNY, F.Inst.P.

The structural characteristics of chromium-manganese steels are discussed, more particularly as affected by prolonged heating at high temperatures. Recent important investigations on the subject are also discussed.

A SURVEY of the various ferrous alloys which are used for heat-resisting purposes indicates very quickly that chromium is probably the predominant alloying metal. Certain chromium steels—sensibly free from any other alloy—perform very creditably as heat-resisting steels under defined conditions, but the latter are somewhat restricted owing largely to the lack of toughness of many high chromium steels at ordinary temperatures, also their meagre strength and tendency to undergo marked grain growth at elevated temperatures. These effects become apparent when the chromium content exceeds about 14%, an amount sufficient to give adequate scale resistance at temperatures up to only 750° or 800° C. Better properties, both at ordinary and high temperatures are obtained by the addition of enough nickel to produce a stable austenitic structure, and steels of this type are widely used.

The amount of nickel required to do this effectively is appreciable, though not perhaps as great as is sometimes imagined. In many cases 8 or 10 or 12% is sufficient, and rarely is it necessary to exceed 20%, but even these amounts, with the present price of nickel, lead to an appreciable increase in the cost of steel and hence efforts have been made to replace this metal—wholly or partly—by one less costly which would have a similar effect in producing the desired austenitic structure. As manganese is cheaper than nickel and is known to stabilise austenite, it has been regarded as a likely substitute. From a practical point of view, manganese also appears to have a further advantage ; chromium-manganese steels do not seem to be attacked by sulphurous gases at high temperatures in the same manner as chromium-nickel steels.

The value of a heat-resisting steel depends on several factors, among the chief of which are its stability against oxidation, its strength at high temperatures and the constancy of its properties when held for long periods at these temperatures As the last two factors are concerned ultimately with the structure of the steel, it may be convenient to consider first the structure of chromium-manganese steels as affected by composition and heat-treatment, and afterwards to give a more detailed account of those steels which appear to have suitable structural characteristics.

The effect of increasing amounts of manganese on the structure and properties of low carbon, high chromium steels has been studied by Becket,[1] Köster,[2] Günzberg, Aleksandrova and Geldermann,[3] Schmidt and Legat,[4] and Brühl.[5] Becket's investigations were confined to steels with a chromium content of about 18%, and he was concerned more with corrosion resistance than with heat resistance. He showed that when manganese exceeded about 7%, a duplex structure of ferrite and austenite was obtained which he considered was suitable for material required to have good deep drawing properties. Günzberg and his co-workers also studied steels containing about 18% chromium, together with various amounts of manganese and nickel, both singly and together. They found that, in the absence of nickel, even 16% manganese did not produce a completely austenitic structure in 18% chromium steel, and concluded from the result of all their tests that nickel was about twice as effective as manganese in forming austenite. The other investigators tested steels over a much wider range of composition and, in the main, their results agreed fairly well. One of the most interesting of these results related to the question, mentioned above, of the capacity of manganese to form austenite. These latter investigators all concluded that it had little, if any, effect in this direction ; in other words, they considered that that amount of austenite produced in a chromium-manganese steel at high temperatures is almost entirely a function of its chromium and carbon contents. Addition of manganese, they say, does not increase this amount appreciably, but it does increase very markedly the stability of the austenite at lower temperatures ; thus it reduces the critical cooling velocity necessary to give retained austenite, and it makes the latter more resistant to tempering. It would appear that the opinion of Günzberg and his co-workers is in marked disagreement with this result, but it may be mentioned that the latter refers specially to the effect of manganese—or lack of it—in producing a completely austenitic steel, and that in the case of duplex steels, both Köster, and Schmidt and Legat obtained results in agreement with those of Günzberg.

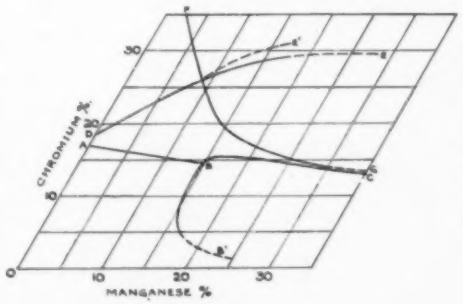


Fig. 1.—Structural characteristics of Fe-Cr-Mn alloys containing about 0.1% carbon (Schmidt and Legat).

Schmidt and Legat embodied their results on steels containing about 0·1% carbon in a diagram which is reproduced in Fig. 1, and this illustrates their views as to the negligible effect of manganese in widening the range of composition of steels which are wholly austenitic at high temperatures. The diagram shows the structural conditions at 1,100° C., and at ordinary temperatures, in their alloys which continued from 5% to 30% chromium, with various amounts (5—35%) of manganese. Structural conditions at 1,100° C. enabled the alloys to be divided into three classes by the lines A B C and D E. Alloys in the area below A B C consist of austenite, and those above D E of ferrite. Alloys whose compositions fall between these two lines have a duplex structure of ferrite and austenite. As regards structures at atmospheric temperature Schmidt and Legat's observations were made on samples

1 F. M. Becket. "Chromium-Manganese Steels." Yearbook, Amer. Iron and Steel Inst., 1930, p. 173.
2 W. Köster. "Die Eisenecke des Systems Eisen-Mangan-Chrome." *Archiv. f.d Eisenhuttenw.* Vol. 7 (1933-1934), p. 687.
3 Günzberg, Aleksandrova and Geldermann. "Eigenschaften von nichtrostenden Chrom-Mangan-und Chrom-Nickel-Mangan-Stählen." *Archiv. f.d. Eisenhuttenw.* Vol. 8. (1934-1935) p.121.
4 Schmidt and Legat: "Hitzebeständige Chrom-Mangan-Stähle." *Archiv. f.d. Eisenhuttenw.* Vol. 10 (1936-37). p. 297.
5 F. Bruhl. "Gefüge und Eigenshaften von Chrom-Mangan-Stählen mit Gehalten bis 1% C, 15% Mn, und 30% Cr." *Archiv. f.d. Eisenhuttenw.* Vol. 10 (1936-37), p. 243.

quenched in water from 1,100° C., and this fact must be kept in mind in considering their results which are as follows. At atmospheric temperature, the austenitic area lying under A B C is divided by a line B B′. Alloys to the right of this line contain stable austenite ; in those to the left, the austenite existing at 1,100° transforms more or less completely to martensite on cooling. In the area A B B′ the structure of the alloys changes with increasing manganese content from ferrite, through martensite to mixtures of the latter with increasing amounts of austenite. Steels whose composition lies in the duplex field between A C and D E have a structure at room temperature of mixtures of ferrite and austenite, up to a content of about 15% manganese, the austenite can transform wholly or partly into martensite, this change actually being complete at low manganese contents.

These descriptions and also the diagram are quoted in the manner given by Schmidt and Legat, but some comment may be useful. In the first place, it is difficult to see why line A B C has been given the form indicated. There appears to be nothing in the data quoted in their paper which would justify the peculiar break at B. Point A at approximately 17% chromium is obviously wrongly placed ; with a carbon content of about 0·1%, a structure consisting entirely of austenite would certainly not be obtained at 1,100° C.—or any temperature for that matter—at a higher chromium content than 14% ; in fact, 13% is probably nearer the limiting value. The steels actually tested by Schmidt and Legat had manganese contents of 3·7% and upwards, and the results from these suggest that A B C should take the form of a smooth, flat curve, lying between 14 and 15% chromium, and possibly rising to a maximum at about 15% manganese. As A B C marks equilibrium conditions at 1,100° C. whereas B B′ merely indicates the limiting composition of austenite which does not break down at temperatures four or five hundred degrees lower under the specific cooling conditions adopted, there appears to be no valid reason why the junction of the two curves should cause a sharp bend in A B C, such as is indicated in the diagram. Actually, according to the results given in the paper, line B′ B should be continued across the duplex area, as it is mentioned that the austenite, in steels in this area which had a low manganese content, transformed to martensite on cooling, whereas at higher manganese contents, the austenite was retained more or less unchanged at room temperature. The conditions are therefore similar to those in the austenitic area below A B C.

Further, it should be noted as mentioned earlier, that the structural conditions which were described by Schmidt and Legat as existing at ordinary temperatures were obtained in all cases from relatively small samples which had been quenched in water from 1,100° C. Much slower rates of cooling would have led to the production of pearlite instead of martensite and also the separation of a larger amount of ferrite in steels of low manganese content, and very probably would have altered the position of the line B B′.

The shape of the curve D E is interesting as it shows that although the addition of manganese may not increase in any marked degree the range of composition from which a completely austenitic structure is obtained at high temperatures, it does widen considerably the range having a duplex $\alpha + \gamma$ structure by causing some austenite to be formed in high chromium steels which otherwise would be ferritic. As a corollary, one would also expect that additions of manganese would increase the amount of austenite in a duplex steel in the manner found by Becket and by Günzberg for steels containing about 18% chromium.

Köster also noted that raising the manganese content of duplex alloys increased the austenite-ferrite ratio ; thus he remarks that in 15% chromium alloys, the amount of austenite at low manganese content was very small, but rose with further additions of this metal, the austenite eventually becoming the major constituent.

Incidentally, it should also be mentioned that point D —with zero manganese—appears to be as wrongly placed as is point A. In the case of D, however, too low a chromium content has been selected ; the writer of this article found an appreciable amount of austenite in steel containing 0·1% C and 20·4% Cr after quenching from 1,100° to 1,200° C.

Prolonged annealing at temperatures between 500° and 850° C. showed that the structures obtained by quenching from 1,100° C. were unstable in many cases, the most striking effect being the production of the compound FeCr in some of the steels investigated ; when this occurred, the steel became very brittle and frequently its hardness increased considerably. After annealing for 40 hours, the compound was obtained in all steels above the line F G ; the authors state, however, that increasing the duration of annealing would move this line to lower chromium contents so that with very long periods, it would approach B C. The compound is formed by the breakdown of the chromium-rich ferrite, the balance of the latter—owing to depletion of chromium and the concentration go the manganese in a smaller amount of iron—changing, partly or wholly, to austenite. As a result of the latter action, the position of the line D E in annealed samples is raised to D E′, the alteration occurring in the area above the line F G. One would expect that a similar effect would be produced on line B C at high manganese contents.

The effect of long-continued annealing on physical properties may be illustrated by a few typical examples. Steels containing about 4% to 9% manganese and up to 14% or 15% chromium consisted mainly of martensite when quenched from 1,100° C. ; they had a fairly high Brinell value which was reduced gradually with rising tempering temperature. Their impact value was low, and remained low after tempering. Results from a steel containing 0·08% C, 10·2% Cr, and 7·5% Mn are given by Schmidt and Legat as typical of this group, and are quoted in Table I.

TABLE I.

(0·08% C. 7·5% Mn. 10·2% Cr.)

Treatment.	Brinell Value.	Impact Value.* Mkg/cm².
W.Q. 1,100° C.	440	
,, annealed. 510° 90 hours	430	
,, ,, 580° 40 hours	420	1 mkg/cm² or less in each case.
,, ,, 650° 40 hours	410	
,, ,, 710° 30 hours	390	
,, ,, 850° 30 hours	260	

Charpy Mesnager. Mkg/cm.²	Izod. Ft. lbs.
2	5
4	10
8	30
12	55
16	75
24	100

It may be mentioned that this relationship is entirely empirical and was determined by making comparison tests on the two machines from similarly treated bars.

*All the impact tests mentioned in this paper were done on a Charpy machine usin test-pieces 10 mm. square, notched with a Mesnager notch (2 mm. deep, 1 mm radius) As tests of this type are uncommon in this country, the following approximately equivalent Izod values may be useful.

The persistence of the martensite in this steel during prolonged tempering—even up to 710° C.—is remarkable ; in the absence of manganese, the hardness would have fallen rapidly on tempering above about 500° C., and incidentally, the toughness would have increased very markedly.

Steels containing 12% to 15% Cr, and between about 10% and 15% manganese, consisted of mixtures of martensite and austenite after quenching from 1,100° C., and their behaviour on annealing appeared to depend on the relative amounts of these constituents. Steel A in Table II, for example, is described as consisting of martensite with some austenite when quenched, and the increase in hardness on annealing at 710° to 800° is put down to the breakdown of residual austenite to martensite. On

the other hand, steel B is stated to have consisted of austenite when quenched, some martensite being also present after annealing (the steel becoming weakly magnetic), although there is no corresponding increase in hardness ; one may also note the much greater toughness of this steel.

TABLE II.

Treatment.	Steel A. C, 11% ; Cr, 13.2% ; Mn, 9·9%.		Steel B. C, 0·04%; Cr, 12·9%; Mn, 13·0%.	
	Brin.	Impact	Brin.	Impact
W.Q. 1,100°.	350	9 mkg/cm²	220	21 mkg/cm²
annealed 510° 90 hours	320	9·5 ,,	220	13·5 ,,
,, ,, 580° 40 hours	310	8·5 ,,	220	14·5 ,,
,, ,, 650° 40 hours	320	2·2 ,,	225	13·5 ,,
,, ,, 710° 30 hours	370	1·8 ,,	225	14·5 ,,
,, ,, 800° 30 hours	370	1·9 ,,	215	16·5 ,,
,, ,, 850° 30 hours	295	1·5 ,,	190	16·2 ,,

A steel containing 0·09% C, 12·9% Cr, and 15·3% Mn gave results similar to those of steel B above, except that no microscopic evidence was obtained of the production of martensite on annealing, and the steel also remained non-magnetic. Increasing the manganese content to about 22%—the carbon and chromium remaining as in the last sample—led to a Brinell value of about 180 being obtained after all treatments ; in addition, the impact value was uniformly high—about 20 mkg/cm² or over.

Raising the chromium content to over 15% brought the steels into the range of duplex structure ; the properties then obtained depended on the relative amounts of ferrite and austenite, the stability of the latter, and whether or not the compound FeCr was formed from the ferrite, the last-named feature being possibly the most important.

A steel containing 0·05% C, 15·4% Cr, and 13·0% Mn consisted of austenite and ferrite when quenched—austenite being the main constituent—and had a Brinell value of 190 combined with great toughness (36 mkg/cm²). On annealing the Brinell value rose to a maximum of 295 at 650°/710°, whilst the impact value dropped to a low figure, 2—5 mkg/cm² ; Schmidt and Legat remark that the austenite was partially changed to martensite. Annealing at 800°/850° reduced the Brinell value to 230/220, the impact value rising to 8/10 mkg/cm².

With 22·2 Cr and 9·3% Mn the steel was still in the duplex range, but contained more ferrite than the sample last described. This steel had a Brinell value of 240 when quenched and moderate toughness (6 mkg/cm²). On annealing, the Brinell rose slightly, but the steel was completely embrittled. The last result is interesting, as this steel lies well outside the curve F G in Fig. 1.

Reducing the manganese content (the chromium remaining at about 22%), or increasing the chromium brings the steel into the α — range, and such steels (provided they lie to the left of the line F G) behave in a similar manner to high chromium steels. They have a low impact value coupled with an almost unvarying Brinell value of 200 to 230.

Finally, there are the steels which form the compound FeCr on annealing and which, as a result, become completely embrittled. If these consist wholly or mainly of ferrite in the quenched condition, due to a high chromium content, their hardness increases very markedly when annealed, the increase not being so pronounced in those containing less chromium, whose structure, in the quenched condition contains a fair proportion of austenite ; the latter steels, of course, are also tough as quenched. Some typical figures are given in Table III, steel A being mainly ferritic as quenched, whereas B had a duplex structure.

The production of the intermetallic compound FeCr at a chromium content as low as 15%—four steels containing 14·0/15·7% Cr and 27·3/35·0% Mn were stated to be completely embrittled on annealing—is of considerable interest. Schmidt and Legat consider this may be due to the ferrite in such duplex steels having a much higher chromium content than the austenite. Brühl, whose data will be considered later, also mentions this, and both authors refer to the work of Köster[2] who investigated a number of iron-chromium-manganese alloys containing up to 30% Cr and 40% Mn. Köster determined roughly the composition of the α, $\alpha + \gamma$, and γ fields at temperatures

TABLE III.

Treatment.	Steel A. C, 0·15%; Cr, 25·9%; Mn, 11.2%.		Steel B. C, 0·2%; Cr, 21·3%; Mn, 19·2%.	
	Brin.	Impact.	Brin.	Impact.
W.Q. 1,100° C.	250		220	17 mkg/cm²
,, annealed 510° 90 hours	490		420	
,, ,, 580° 40 hours	510		450	
,, ,, 650° 40 hours	600	1 mkg/cm² or less.	450	Very low, less than 0·5 mkg/cm²
,, ,, 710° 30 hours	690		460	
,, ,, 800° 30 hours	540		450	
,, ,, 850° 30 hours	295		400	

between melting point and 800° C. At the latter temperature, he considered that, in alloys containing 10% to 20% manganese, the duplex area extended from about 13% to 26% chromium ; above 26% they were wholly ferritic, and below 13% austenitic, though the austenite in the latter alloys might, of course, transform at Ar ·3 on cooling, and proably would if the manganese content did not exceed about 10%. Assuming that Köster's values are correct—and it may be noted that he gives very meagre data in his paper and, in particular, no details regarding the composition of the alloys beyond their chromium and manganese contents—the duplex steels would consist of a mixture of austenite containing about 13% chromium and ferrite containing about 26%. Even the latter value, however, is lower than the range of chromium content within which formation of the compound FeCr has been observed in iron-chromium or iron-chromium-nickel alloys. Probably, for this reason, Schmidt and Legat consider it possible that manganese displaces the range of composition in which the compound is produced to a lower chromium content—a fact which would appear to be self-evident from their results—or even enters into the compound itself.

All the results obtained by Schmidt and Legat refer to steels containing about 0·1% carbon. Brühl[5] also investigated steels of similar carbon content and, in addition, others containing up to about 1%. His steels contained 15%, 20% and 30% chromium, in each case with 5%, 10% and 15% manganese. Each of these nine composition groups contained at least five steels, whose carbon contents were approximately 0·1%, 0·25%, 0·5%, 0·75%, and 1·0%. The greater part of his observations were in respect of the structure, hardness and magnetic properties of samples which had been heated for an hour at either 1,000°, 1,100° or 1,200° C., and then quenched in water, and the effects produced on these samples by subsequent annealing for eight hours at 500°, 600°, 700° and 800° C.

TABLE IV.

Values of Brinell hardness and maximum inductance of samples water quenched from 1,200° C.

Composition.		5% Mn.		10% Mn.		15% Mn.	
C %.	Cr %.	Brinell.	B. Max. Gauss.	Brinell.	B. Max. Gauss.	Brinell.	B. Max. Gauss.
0·1	15	278	15,400	211	5,980	183	800
0·28	15	216	285	208	45	183	40
1·0	15	257	21	272	12	200	12
0·1	20	192	13,380	198	7,800	189	7,800
0·5	20	252	925	229	263	224	1300
1·0	20	283	28	294	15	299	12
0·1	30	214	11,690	242	10,420	295	9,200
1·0	30	225	10,770	231	9,580	285	7,800

Hardness and magnetic saturation values from some of the steels, after quenching from 1,200° C. are given in Table IV. On the assumption that a value of 500 gauss, for maximum inductance, may be regarded as being the limit for austenite, Brühl concludes from these results that

with alloys containing 15% chromium, carbon content must exceed 0·3% in order to preserve an austenite structure after quenching whether the manganese content be 5%, 10% or 15%. To obtain a similar result at 20% chromium requires a minimum of 0·5% carbon, whereas at 30% chromium no austenite is formed, even with 1% carbon and 15% manganese. He further concludes that manganese is practically without effect on the formation of austenite, carbon and chromium being the decisive factors in this direction. It may be suggested that these are rather sweeping conclusions to base on such meagre data and that in any case, the steel containing 15% chromium and 15% manganese appears to be almost completely austenitic with 0·1% carbon, a result which would not have been obtained if the manganese had not been present.

Considering his results in some detail, it may be noted that the lowest carbon steels of the first group, were apparently mainly ferritic as quenched and no great change in hardness or magnetic saturation value was produced on annealing. The higher carbon steels, when quenched, consisted mainly of austenite, together with free carbide; the austenite, however, broke down to martensite on annealing, and this, together with the precipitation of carbide previously in solution in the austenite, led to a marked increase in hardness; the latter rose progressively with annealing temperature up to 800° C. in the 15% chromium steels, but reached a maximum at 700° C. in those containing 20%. Fig. 2 gives typical values for hardness and inductance.

These results indicate, as did those of Schmidt and Legat,

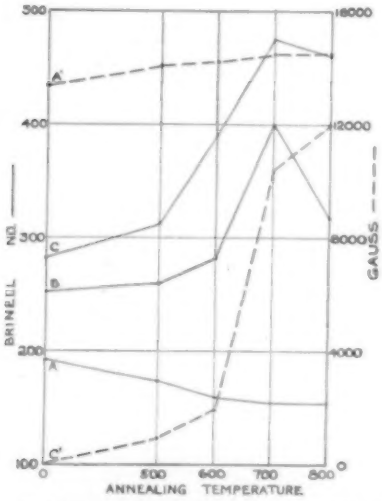


Fig. 2.—Effect of annealing on the hardness and maximum inductance of steels containing 5% manganese and 20% chromium (previously W.Q. 1,200° C.).

Curves A and A'	.. .. ..	0·07% carbon.
„ B	.. .. ..	0·5% „
„ C and C'	.. .. ..	1·02% „

Microstructural examination of the quenched samples was, however, broadly in agreement with the conclusion that the addition of manganese to high chromium steels does not widen appreciably the gamma field at low carbon content, but that its effect is principally that of stabilising the austenite, which is formed at high temperatures, by lowering its critical cooling rate and making it far more resistant to prolonged tempering. As Brühl did not include steels containing between 20% and 30% chromium in his investigations, his results do not indicate whether manganese widens the duplex field in the manner shown by line D E in Schmidt and Legat's diagram, Fig. 1.

Brühl subjected his quenched samples to eight-hour periods of annealing at 500°, 600°, 700° and 800° C., and measured the effects thereby produced on structure, hardness and magnetic saturation. In the light of his results he classified the steels in three groups having the following ranges of composition :—

Group I ..	0—1% C;	15—20% Cr;	5% Mn.
„ II ..	0—1% C;	15—20% Cr;	10—15% Mn.
„ III ..	0—1% C;	20% Cr;	5—15% Mn.

He briefly summarises the characteristic features of these three groups in the following manner. Steels of the first group may certainly contain austenite when quenched, but it is not stable; it breaks down on annealing. Those of group II consist of austenite or austenite and ferrite when quenched: the austenite is stable on annealing, but the ferrite changes into the compound FeCr and austenite. The steels in the third group are ferritic; they do not form austenite and when annealed they go over more or less completely to the compound FeCr.

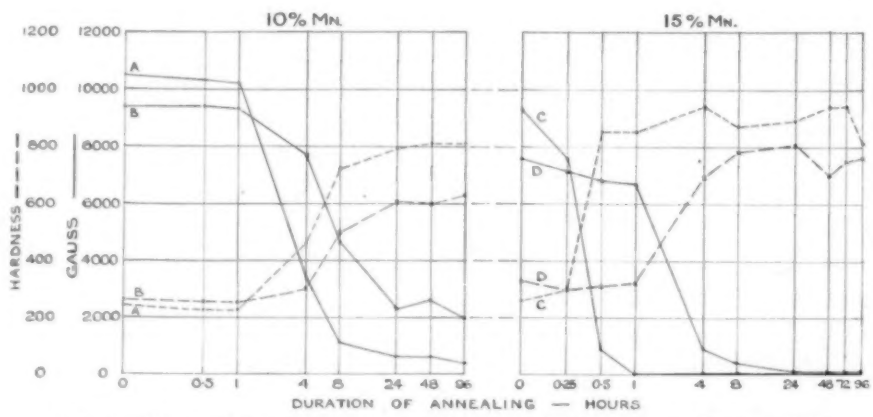


Fig. 4.—Effect of duration of annealing, at 700° C. on hardness (Firth hardometer), and maximum inductance of 30% chromium steels (samples previously W.Q. 1.200° C.).

	C. %.	Mn. %.	Cr. %.
Curve A..	0·09	10·3	30·2
„ B..	1·03	10·2	30·3
„ C..	0·10	16·2	27·6
„ D..	0·94	15·8	31·1

that the austenite produced on quenching the 5% manganese steels from very high temperatures is not stable on annealing, though it is much more resistant to the latter than the austenite in steels substantially free from manganese but otherwise similar in composition. Possibly more useful properties would have been obtained from these steels by air cooling from a lower temperature, 900° or 950° C. (which would have taken less carbide into solution and hence tended so give a martensitic rather than an austenitic structure), and then tempering at about 700° C.

The results obtained from steels of the second group possess several interesting features. In the case of the 15% chromium steels, the chief effect of increasing the manganese content to 10% or 15% appeared to be the greatly enhanced stability of the austenite. At 10%, the highest carbon steel (1·07%) remained austenitic after eight hours annealing at all the temperatures used, although some increase in hardness occurred (the approximate Brinell values being 275/340), probably as a result of carbide precipitation. On the other hand, magnetic tests on the lowest carbon steel (0·05%) indicated that the austenite in this broke down on annealing at 600° to 800° C.; there was also a considerable increase in hardness. No magnetic data are given for the 15% chromium, 15% manganese steels, but one may gather from Brühl's comments that the austenite in these steels was stable on annealing; a rise in hardness was observed, and this was ascribed to carbide precipitation.

The low carbon 20% chromium steels of this group were definitely duplex, and interesting observations were made regarding the formation of the compound FeCr from the

ferrite on prolonged annealing. In the case of the steel containing 0·15% C, 19·7% Cr, and 10·4% Mn—which it may be noted lies well outside the range of composition given by Schmidt and Legat in Fig. 1, for the formation of this compound—the effects were presumably noticeable in a rise in hardness value coupled with a fall in magnetic saturation as indicated below.

Treatment.	Brinell Hardness. No.	Inductance. Gauss.
As quenched	198	7,800
Annealed 8 hours at 500°	218	8,200
" " 600°	238	6,200
" " 700°	300	5,000
" " 800°	220	8,200

It has already been mentioned that Schmidt and Legat found that steel of similar analysis was completely embrittled on annealing.

A similar steel, but containing 1·09% C, remained practically non-magnetic after all treatments ; its hardness value rose about 40 units on annealing at 700° C., probably as a result of carbide precipitation. This steel was austenitic as quenched and there was presumably no formation of the compound during annealing. Data are unfortunately not included regarding the steels of intermediate carbon content, but one may suppose that those containing about 0·5% and 0·75% were also austenitic when quenched (see Table IV), and hence would behave similarly to the higher carbon material.

Increasing the manganese content to 15% brings the low carbon 20% chromium steel above line F G in Fig. 1, and in this case, very marked evidence of the formation of the FeCr compound was noticed. As quenched, this steel had a duplex structure of ferrite and austenite, the former being the major constituent. Its hardness value was low (190 Brinell), and its saturation value fairly high, about 8,000 gauss. On annealing for eight hours at either 600°, 700° or 800° C. its hardness rose to 380 Brinell, the saturation value falling to about 500 or less. Fig. 3 indicates that the changes take place gradually, but are practically complete in four hours at 700° C. Microscopic examination showed that annealing produced apparently no change in the austenite, but brought about the formation of a pearlite-like appearance in the ferrite ; this was considered to be due to the precipitation of the compound FeCr, the balance of the ferrite being simultaneously transformed to austenite, as indicated earlier. Raising the annealing temperature to 800° C. led to a balling up of the plate-like compound and to a slight drop in hardness value.

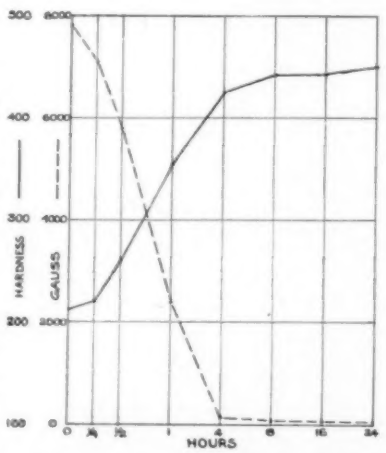


Fig. 3.—Effect of duration of annealing, at 700° C., on hardness (Firth hardometer), and maximum inductance of steel containing 0.15% C, 14.6 Mn, 19.9% Cr (samples previously W.Q. 1,200).

The higher carbon steels containing about 20% chromium and 15% manganese were austenitic and, except for the precipitation of carbide, were stable on annealing. That containing 1·10% carbon, for example, was practically non-magnetic after all treatments and its hardness value rose only 20 units (from 300 to 320) after eight hours at 700° C. Brühl remarks that the carbide thrown out of solution was found partly as an intergranular network, partly on the twinning planes and partly as extremely fine particles scattered through the grains and causing a more or less uniform darkening of the latter on etching.

Brühl sought further evidence, by X-ray examination, of the production of the compound FeCr in these steels. The patterns obtained by the Debye-Scherrer method, from samples of the low carbon steels containing either 15% or 20% chromium, together with 15% manganese, after annealing for eight hours at 700° C. were inconclusive, but increasing the annealing period to 300 hours or more enabled unmistakable evidence to be obtained of the production of austenite and of the compound FeCr. It was not possible to determine whether manganese entered into the compound as the atomic radii of chromium and manganese differ only very slightly. The identification of the compound in the steel containing 0·07% carbon, 15·0% chromium and 15·1% manganese is interesting as the magnetic tests on this steel indicate that, in the quenched condition, it contained only a small amount of ferrite. The decomposition of this, however, led to a marked drop in impact value, as will be seen in the later section.

The steels in group III gave extremely interesting results, a very marked increase in hardness being obtained on

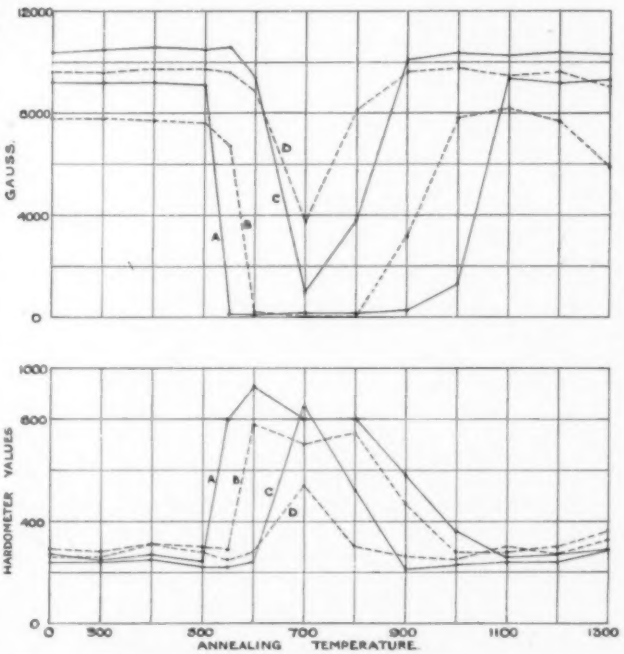


Fig. 5.—Effect of eight hours' annealing at the temperatures indicated on hardness and maximum inductance of 30% chromium steels (samples previously W.Q. 1,200° C.).

	C. %.	Mn. %.	Cr. %.
Curve A	0·11	15·6	30·1
" B	0·94	15·8	31·1
" C	0·09	10·3	30·2
" D	1·03	10·2	30·3

annealing those containing 10% and 15% manganese. Incidentally, some of the annealed samples of these alloys were so brittle that they broke into small pieces under the ordinary Brinell load ; in order to obtain hardness values on these samples, they were tested with a Firth hardometer, under a load of 30 kg. Preliminary tests having indicated that the production of the compound—as judged by hardness and magnetic tests—occurred most readily at 700° C., a study was made of the effect of time at this temperature. The results are plotted in Fig. 4, and they indicate that the rate of formation of the compound is delayed by increasing the carbon content or lowering the manganese content. Both these effects are also evident in the results from the 5% manganese steels ; as shown in Table V, an annealing period of 500 hours produced hardly any effect on the steel of this type containing 1% carbon,

and although the low carbon material showed evidence of the structural change, it was obviously taking place much more slowly than in the steels containing 10% and 15% manganese.

TABLE V.

Annealing tests at 700° C. on steels containing about 30% chromium and 5% manganese

Treatment.	Steel A. ·05% C; 5·7% Mn.; 29·9% Cr.		Steel B. 1·04% C; 5·5% Mn; 29·7% Cr.	
	Firth Hardness.	Max. Ind. Gauss.	Firth Hardness.	Max. Ind. Gauss.
W.Q. 1,200.	190	11,700	250	10,800
,, Annealed 700° C. 100 hours	260	7,700	260	10,800
,, ,, 500 hours	430	5,600	260	10,200

The results of tests to determine the range of temperature in which appreciable formation of the compound occurs during an annealing period of eight hours are shown in Fig. 5. Here again, it is evident that increasing the carbon content or lowering that of the manganese reduces the range of temperature in which the compound is produced. The marked influence of manganese on both the velocity and temperature range of the transformation suggests that this metal enters into the compound, though Brühl states that direct evidence on this could not be obtained. The effect of carbon is probably due to the formation of carbides of chromium and manganese reducing the amount of these metals available for production of the compound.

X-ray photographs were also obtained from the steels containing 30% chromium, 15% manganese and 0·1% and 1·0% carbon, respectively, the samples being heated for 30 mins. at 1,200° C., quenched in water, and then annealed for 96 hours at 700° C. The photographs showed the presence of the compound only; no evidence of γ-iron could be found. It is to be assumed therefore that during the annealing the ferrite in these steels had been converted completely into the compound.

It may also be noted that dilatation curves on these steels indicated that the formation of the compound is accompanied by a marked decrease in length of the test-bar, and this throws an interesting light on the behaviour of the steels during forging. In the preliminary trials, the ingots containing 30% chromium and 15% manganese were unforgeable, irrespective of their carbon content; they broke into pieces merely on heating in the furnace. These ingots had been cooled in the moulds after casting; the volume changes and the high hardness resulting from the formation of the compound during this cooling, and the subsequent reheating for forging produced internal stresses which fractured the ingot before forging commenced. Further ingots were subsequently cast and were stripped from the moulds before the temperature fell below 950° C. They were then charged into a furnace at that temperature, heated to 1,020°, and then forged, being reheated again to 1,020° when the temperature fell to 900° C. When forging was complete, the material was cooled off in water. Under these rather restricted conditions, which prevented the formation of the compound, forging was carried out without trouble.

It is obvious that these various structural changes which have been described preclude the use for heat-resisting purposes of chromium-manganese steels in certain ranges of composition. The most useful type of steel would appear to be one which can be made completely austenitic, and if the carbon content be limited to about 0·15%, such a structure can only be obtained when chromium does not exceed about 15%. The ferritic chromium-manganese steels appear to be entirely unsuitable and a similar remark applies to the duplex steels, except possibly those of relatively low manganese content. In the next part of this article it is proposed to consider in more detail the properties of the alloys in those ranges of composition which appear to have sufficient structural stability to warrant their use as heat-resisting steels.

Resistance Welding Progress

Increasing Use in Metal Manufacturing Industries.

THE steady and rapid improvement of resistance welding as a production method in the metal manufacturing industries was described at a recent meeting of the Midlands Branch of the Institute of Welding, by Dr. F. R. Hensel, Consulting Metallurgist to P. R. Mallory and Co., Inc., Indianapolis, and to Mallory Metallurgical Products, Ltd., Croydon.

Manufacturers of automobiles, aircraft, refrigerators, and metal specialities, said Dr. Hensel, had realised that they must produce structures incorporating strength, light weight and beauty of design, while keeping the cost to a minimum, and resistance welding methods had made this possible at a speed unequalled by any other process. One of the more popular American cars, for example, contained a total of 3,240 resistance welds on the body and chassis, consisting of 44 flash butt welds, 3,194 spot welds and two seam welds, while in the aircraft industry the spot and seam welding of secondary structures had become established practice. Manufacturers of metal containers, office furniture, steel barrels, washing machines, vending machines, bicycles, window frames, typewriters and refrigerators, who had previously employed riveting, bolting, soldering, gas or arc-welding as means of assembly had also realised the advantages connected with a change to resistance welding methods.

Modern spot welding was practiced in an ever-increasing variety of ways. The conventional type of machine made one weld at a time, but there were also machines consisting of fixtures in which the parts were assembled and in which a number of spots were made at the same time by parallel electrodes. One machine of this type welds a motor car door, making a total of 32 welds in one operation. In another machine, of the hydromatic type, a number of welding guns are mounted in pre-determined positions and a control mechanism automatically operates the guns in sequence and in rapid succession. On this machine a motor car floor board, consisting of twenty pieces, may be completely assembled.

Seam welding machines, having a maximum welding speed of 30 feet per minute, have been developed for the manufacture of petrol tanks and refrigerator linings, while the flash welding method is employed for welding motor car bodies and rear axle casings.

One of the most essential parts of the resistance welding machine is the die or electrode material. Originally copper was used, but it proved to have too short a life on many of the automatic machines to give the required results. It had therefore been necessary to develop special copper-tungsten and other alloys, such as Elkaloy and Mallory alloys, having great wear resistance, good electrical and thermal conductivity and high strength at red heat. These materials give a life ranging from three to twenty times that of copper.

In concluding his lecture, Dr. Hensel said that the metal manufacturing industries had solved a great number of problems in applying electric resistance welding methods to their manufacturing processes and in increasing the speed of production without sacrificing the quality of the weld. While at present definite limitations prevailed as to size and thickness of materials to be welded, future development would unquestionably show ways of applying resistance welding methods in the production of heavier sections and structural parts now being made by gas or arc-welding, or by hot rolling or casting.

New Sheet Rolling Mill at Zaporozhe

A NEW sheet-rolling mill at the Orjonikidze Iron and Steel Works, in Zaporozhe, has been put into operation, and has turned out its first 1,000 tons of sheet metal. The mill, which is said to be one of the most powerful in Europe, is designed for an annual output of 280,000 tons of sheet metal.

High-Duty Brasses and Bronzes Available to the Engineer

Their Properties and Applications

By E. Hudson

High Duty Bronzes

In a previous issue the properties and applications of some modern high-duty alloys were discussed under the grouping of high-duty brasses; and in the present article the author deals with those alloys containing an appreciable quantity of tin which constitute the true bronzes.*

THE majority of the brasses employed in engineering are undoubtedly fabricated—i.e., in the form of rolled, drawn or extruded shapes, but this feature is completely reversed in the case of the bronze group which is largely produced in a great variety of cast forms covering a wide range of compositions. In a short article of this nature it is impossible to mention all of the bronzes available, but Table I will probably indicate those likely to be of particular interest for high-duty service.

Admiralty Gunmetal

Whilst the majority of the bronzes are utilised for the production of castings, fabrication by cold working is practised in certain instances producing material with remarkably fine physical characteristics. For example, that well-known alloy 88/10/2 or Admiralty gunmetal, has been available in this country for some years in the form of cold-rolled bars when it has a tensile strength of 50 tons per sq. in. with a Brinell hardness of 220 in conjunction with good ductility and shock-resisting properties. In this latter form it has been used for slow-speed, highly-loaded unlubricated bearings such as are required in hydraulic engineering and water-power control—i.e., submerged roller bushes and sleeves for sluice gates. Similar remarks apply to phosphor-bronze alloys containing around 95% copper when they are used in the fabricated form for bearing bushes and wire products such as springs and flexible cables, etc. There is a large and profitable future field for further extension in connection with the production of fabricated bronze sections, and in view of latest advances in non-ferrous metallurgical practice future developments can undoubtedly be anticipated.

Low Nickel Bronzes

When one considers how the advent of alloy steels has revolutionised ferrous metallurgy and made possible the wonderful engineering products of modern times, investigation of the effect of similar alloy additions to non-ferrous materials is an obvious sequence, and has resulted in the production of bronze particularly suited for high-duty service in many branches of engineering. Whilst development of these special bronzes are as yet in their infancy, enough information and practical experience has been gained to place them on a sound basis and to indicate that with extended research, coupled with the necessary amount of engineering interest, they are likely to be of outstanding value and may possibly revolutionise non-ferrous metallurgy in a way comparable to that brought about in ferrous interests by the advent of alloy steel. There is a very close similarity so far as research is concerned inasmuch as nickel, being possibly the first metal added in the past to steel, is now being extended to brasses and bronzes and additions of other metals such as chromium, molybdenum, etc., will assumedly follow.

Small additions of nickel to bronzes are beneficial in many directions. For example, if a portion of the tin is replaced by nickel in the 88/10/2 alloy not only are improved mechanical and other physical properties obtained, but at present market prices this substitution is of economic importance as in view of nickel being cheaper than tin the cost of the bronze is reduced in many cases. In 1928 the author conducted an investigation on Admiralty gunmetal, and the effect of adding 5% nickel to replace an equal percentage of tin when the following average results were noted in the " as cast " condition :—

Composition.				Tons per sq. in.		Elongation. % on 2 in.	Brinell. (500 Kg.)
Cu.	Sn.	Zn.	Ni.	Maximum stress.	Yield point.		
88	10	2	—	17·30	8·0	17·5	74·1
88	5	2	5	18·25	8·5	24·0	70·5

It is interesting to observe the appreciable increase in ductility and toughness of the alloy containing nickel. As well as obtaining improved physical properties the addition of nickel undoubtedly gives greater density and also permits wider latitude in foundry practice, particularly as regards pouring temperature. The full benefit of nickel additions to bronze is however not apparent until they are heat-treated, when temper-hardening is brought about and very useful properties obtained, as shown in Table I. It is rather remarkable to observe that by substituting nickel for 5% tin in Admiralty gunmetal castings and giving a simple heat-treatment, maximum strengths of 37 tons can be obtained with 16% elongation on 2 in. and a Brinell hardness of 171.

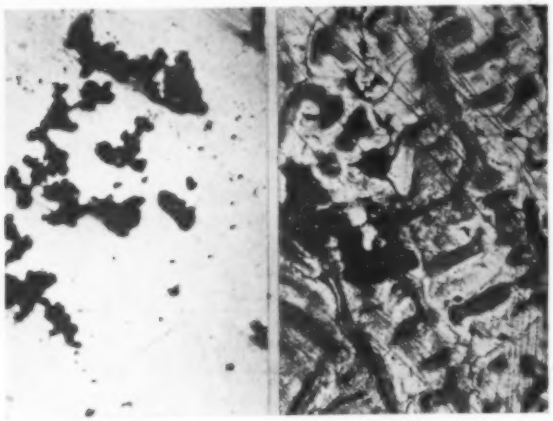
Such properties are equal to those obtained from high-tensile brass, and are not unduly difficult to obtain in actual practice. Further work conducted by Wise and Eash show that by using an alloy containing 7·5% nickel and 8·0% tin, after temper-hardening, maximum strengths in the neighbourhood of 49 tons can be obtained with 6% elongation and hardness values of 228, and, by cold-rolling and hardening, the maximum strength is increased to 75 tons per sq. in. with 1·5% elongation on 2 in. with a Brinell hardness of 392.

The majority of these results were arrived at in the laboratory, but from recent work conducted by the writer under practical conditions sufficient evidence has been obtained to confirm the future value of these alloys and the remarkably fine physical properties available. There are many high-duty parts in all branches of engineering which could profitably be made in bronzes of these class, such as, for example, highly stressed gears and pinions, special bearing bushes, dies for plastic manufacture, impellers and liners, valve guides, valves, etc.

Up to 5% nickel the alloys are easily handled in the foundry and castings are no more difficult to produce than ordinary gunmetal and bronze, but, with higher nickel percentages. the technique required becomes more critical, and particular care must be taken to ensure the absolute absence of interdendritic shrinkage such as shown in Fig. 1. Whilst a small amount of this defect is not uncommon in the average commercial casting its presence is absolutely fatal to those alloys which must subsequently be temper-hardened and prevents the maximum properties being obtained, particularly so far as elongation is concerned.

* *Metallurgia*. October, 1937.

Special precautions, therefore, must be taken during melting to prevent gas absorption, and a satisfactory deoxidation treatment given before pouring into the mould. Furthermore, the casting must be run in a modified method to that usually adopted for the tin-bronzes embracing choke gates and heavier feeding risers as shown in Fig. 2. The presence of even a trace of lead in the alloy is also



Polished. Etched.

Fig. 1.—Interdendritic shrinkage in bronze. × 50.

critical to the production of high test values, and this must be definitely excluded from the composition.

It should also be pointed out that at least 4% nickel and 4% tin are required for appreciable temper-hardening to take effect and the alloys become increasingly susceptible to treatment as the nickel and tin contents rise up to 8·0%, slowing down again as this limit is passed. From the preceding remarks it is evident that the low-nickel bronzes with their high strength and hardness, so simply and inexpensively secured, open up entirely new fields for non-ferrous castings in engineering and give to the practical foundryman a ready means of unification whereby a single metal with its wide range of properties can replace the multiple mixtures previously required.

For further information on the improvement of various cast bronzes reference should be made to the work of Pilling and Kihlgren[1] wherein it is shown that the type and composition of the alloy used has an important bearing on the percentage nickel addition required. For example, in the case of steam bronze containing 85% copper, 5% tin, 5% zinc, 5% lead, nickel additions up to 1·5% give a progressive increase in the tensile strength, yield point and elongation, but a drop in ductility is experienced on increasing the nickel to 3·0%.

In the case of bearing bronze containing 80% copper, 10% tin, 10% lead the effect of nickel is similar to tne above, except that if an all round improvement in mechanical properties is desired the nickel addition must be around 0·5%. Apparently the higher the lead content of the mixture less nickel must be added before combined

[1] "Some Effects of Nickel on Bronze Foundry Mixtures," N. B. Pilling and T. E. Kihlgren. Trans. Amer. Foundrymen's Ass. 1931. Vol. 2, pp. 93–110.

TABLE I.

APPLICATIONS AND MECHANICAL PROPERTIES OF HIGH DUTY BRONZES.

Material.	Composition. %.								Mechanical Properties.					Condition.	Typical Applications.
	Cu.	Sn.	Zn.	Pb.	Ni.	P.	Fe.	Mn.	Y.P. tons per sq. in.	Maximum stress. tons per sq. in.	Elongation. %. on 2 in.	Izod impact. ft. lbs.	B.H.N.		
Admiralty Gunmetal ..	87·24	10·39	2·33	free	—	—	—	—	10	17	17	11	72	Sand cast.	Valve bodies. General engineering and marine castings. Rolled bars used for bearing bushes, etc.
	88·04	10·24	1·63	—	—	—	0·07	—	38	50	19	24	220	Cold rolled.	
Low Nickel Bronze[a]	88·0	5·0	1·75	—	5·0	—	—	0·25	10	22	44	—	75	Sand cast.	High-duty engineering, marine, automobile and aircraft castings, bearing bushes, cylinder head covers, liners, etc. Gearwheels. Levers. Valve spindles and operating mechanism. Rollers and cams.
									24	33	27	—	136	Heat 760° C. for 10 hours. W.Q. Reheated 260° C. for 5 hours W.Q.	
									29	37	16	—	171	Heated 760° C. for 10 hours. W.Q. Reheated 316° C. for 5 hours W.Q.	
Bearing Bronze	88·71	10·47	—	—	0·75	0·023	—	—	12	19	13	—	80	Sand cast.	Engine big-end bearings. Main engine bearings. Journal bearings.
	79·25	10·0	—	10·0	0·75	—	—	—	9	14	7	—	64	Sand cast.	
	72·50	1·0	—	25·0	1·5	—	—	—	—	8	8	—	30	Chill cast.	
Phosphor Bronze	88·54	11·19	—	free	—	0·23	—	—	13	22	11	—	108	Chill cast.	General engineering and marine castings. Gear blanks. Bearing bushes. Valve bodies and faces. Springs. Flexible cable.
	95·56	4·23	—	—	—	0·13	—	—	25	28	33	—	138	Rolled and drawn	
	77·50	11·31	—	9·18	0·75	0·28	—	—	10	15	6	—	80	Sand cast.	
High Nickel Bronzes	72·69	5·24	0·80	0·13	20·98	—	—	0·15	15	26	14	19	107	Sand cast.	Valve faces and parts for steam control and other castings for operating at elevated temperatures, or to withstand corrosion. Used in conjunction with hardened 880-type stainless steel for highly-loaded and unlubricated bearing faces (i.e., rotary or slid valves). Turbine labyrint packing rings.
	72·70	6·22	0·64	free	20·08	—	free	0·28	19	27	7	—	138	Sand cast.	
									12	26	12	—	129	Heated 760° C. for 2 hours. W.Q.	
	73·10	7·17	0·68	0·13	18·84	—	—	— Si	19	27	3	3	130	Sand cast.	
	69·59	7·40	1·69	—	29·65	—	0·13	0·5	25	25	¼	1	250	Sand cast.	
	63·10	8·98	7·79	0·35	19·76	—	—	— Al	28	32	1	—	239	Sand cast.	
	32·55	12·72	—	—	53·80	—	0·48	0·32	31	32	½	—	350	Sand Cast.	

[a] Strength and Ageing Characteristics of the Nickel Bronzes. Wise and Eash. Amer. Inst. of Min. and Met. Eng. 1934. (Inst. Met. Div., 1934, CXI, 218–244.)

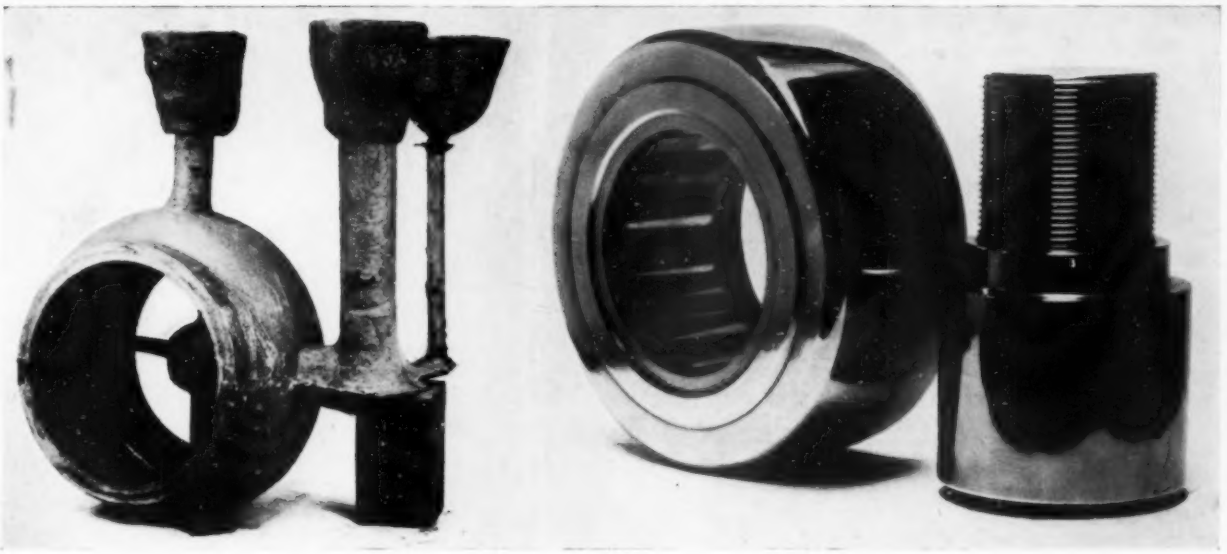


Fig. 2.—Method of running and gating large bronze valve seat containing 20% nickel, 9% tin.

Fig. 3.—Roller-bearing assembly made from cast nickel bronze containing 30% nickel, 7.5% tin, 0.5% silicon, and having a Brinell hardness of 260.

improvements in strength and ductility are obtained. The effect of lead in limiting the nickel content is shown in Table 2.

Recommended nickel additions to cast bronzes for obtaining all round improvement in mechanical properties.

TABLE II.

Alloy.	Composition. %.				Nickel Addition. %.
	Copper.	Tin.	Zinc.	Lead.	
Admiralty gunmetal	88·0	10·0	2·0	—	Up to 5·0
Gunmetal (valve bronze)..	88·0	8·0	4·0	—	Up to 3·0
Gunmetal (Red Brass) ..	85·0	5·0	5·0	5·0	Up to 1·5
Leaded bearing bronze ...	80·0	10·0	—	10·0	0·5 to 1·0

High Nickel Bronzes

Bronzes containing over 14% nickel can be classed as high nickel alloys, and they are extensively employed for valve faces and fittings of all kinds for service with corrosive waters and steam. Those containing around 15 to 20% nickel with 5 to 7% tin are principally used for faces and spindle operating nuts on valves handling corrosive waters such as estuary and sea water, and also for the small non-return valves and seats in pumps together with those for hydraulic relief and safety valves where metal quality above the ordinary range of bronzes is essential for reliable service. The percentage of tin present is critical so far as ductility in the cast condition is concerned, an alloy with 20% nickel and 5% tin having a tensile strength of approximately 26 tons per sq. in. with 14% elongation, and a Brinell hardness number of around 107. (See Table I.) As the tin content is increased to 7% the alloy becomes harder and more brittle, and the elongation drops down to 3%. This, however, can be corrected by annealing or quenching, but if toughness or shock resistance " as cast " is desired, it is important to keep the tin content between 5 to 6%.

Bronzes containing 30% nickel, hardened by the addition of aluminium or silicon, can be produced with Brinell hardness numbers of 250 as cast, and are used for orifice plates for venturi tube measurement of water, heavily-loaded valve faces and roller bearings of various kinds for hydraulic equipment. Fig. 3 illustrates an interesting example of this latter application.

Between 30 and 70% nickel the alloys are very extensively employed for faces for steam-control valves, and are hardened with aluminium, silicon and even with chromium, molybdenum, etc. to give hardness values up to 400 Brinell, nickel appearing to act as a solution agent for these high melting point additions. All the nickel bronzes having a hardness of over 250 provide excellent bearing surfaces under non-lubricated conditions, and work well with the various hardenable stainless steels in applications of this nature, but their particular value rests in the fact that they have the property of being much more stable than the ordinary bronzes at moderate elevated temperatures around 232° to 316° C. (450° to 600° F.). All the hard alloys in the two latter groups are, as can be expected, relatively brittle and unsatisfactory for shock-resisting applications, but they have remarkably high corrosion, erosion and wear resistance under severe operating conditions. It is interesting to note from Table I, that quite apart from the amount of nickel added, the tensile strength of all the alloys remains between 25 and 32 tons per sq. in.

On the whole, very little systematic research has been conducted on the high nickel bronzes, and there is undoubtedly a very important field open in this direction for development. Many of the compositions employed should be capable of temper-hardening, but at present little is as yet known about this matter, so far as these alloys are concerned.

Bearing Bronzes

In any outline of the high-duty bronzes it would be a serious omission not to mention the leaded alloys which are used so extensively in many directions for bearing purposes. So far as mechanical properties are concerned, they are considerably below that normally expected from the free or low lead alloys, but this by no means eliminates them from high-duty service as bearings.

In the past cast phosphor bronze has been used quite extensively for such applications as gudgeon-pin bushes, cam-shaft bearings, valve rocker bushes, etc., but this material has not on the whole proved successful for high-speed service such as big-end crankshaft and journal bearings, where the tin base babbitt metals have been most favoured. However, with the modern tendency of higher loading and increased speeds, trouble due to fatigue failure of the existing babbitt metals has been experienced, and a considerable amount of research is now being directed to both methods of improving the existing and also to the development of new alloys. It has been found that fatigue failure of the babbitt metals can only be positively over-

come in many cases by the use of the copper-lead alloys, as the physical characteristics of this latter material are less affected by temperature. Aircraft engines, almost exclusively, and many automotive engines to-day carry bearings of this alloy.

The alloys most commonly used contain from 15 to 30% lead with around 1% tin together with a small percentage of nickel to prevent lead segregation. All these alloys are extremely sensitive to cooling conditions during manufacture, and they must be chill cast or cooled fairly rapidly to obtain best results. An alloy containing 85% copper, 15% lead has only a tensile strength of around 4 tons per sq. in. with 5% elongation when sand cast, whilst these values increase to 6 tons and 8%, respectively, when chill cast.

Copper and lead will not alloy in the true sense of the word, and consequently they are very liable to segregate, and whilst it has been said that additions of other metals, such as tin and nickel, are theoretically prejudicial to the important factor in bearing metal service of thermal conductivity, from the practical point of view it is considered that the benefits obtained, such as greater homogeneity, outweigh most other disadvantages. Furthermore, it is debatable, in view of the thin metal section employed in bearings of this kind whether thermal conductivity plays any part at all. Additions of nickel prevent lead segregation in three ways. First nickel causes the metal to set more quickly, and in view of what has been previously said in regard to the necessity of chilling this is a distinct advantage. Secondly, an addition of nickel to copper actually increases the solubility of lead in molten copper. Whereas pure molten copper can dissolve only about 38% lead, the addition of, for example 2·5% nickel, enables it to take up 60% or more. This ensures the absence of segregation and a finer dispersion of lead globules. Thirdly, if copper-lead alloys high in lead are overheated, there is a tendency for the liquid emulsion to be destroyed, and they then cannot be chilled or cooled fast enough to prevent serious lead segregation. The addition of nickel very definitely stabilises the emulsion at high temperatures. A marked difference in lead dispersion with and without nickel in these alloys is quite observable under the microscope, particularly in the region of 1·0 to 1·5% nickel, and such a composition is being quite successfully used in practice.

Wecker[2] in a detailed study of the copper-lead alloys suggests that replacement of tin by manganese results in material of improved characteristics. It is claimed that the manganese-containing alloys show less tendency to segregation, and are more easily produced. A typical composition contains 63% copper, 30% lead, 2% nickel, 5% manganese.

In Germany, where the bearing problem is chiefly affected by the restrictions on copper and tin, rather remarkable advances have been achieved in the use of copper-lead alloys by the reconsideration of design in developing the full load-carrying capacity of this material, with a consequent saving of 25 to 30% in weight of metal required. It should be noted that these metals do not " run themselves in," and must be finished to size by fine boring, preferably with a diamond tool. This entails fairly generous clearances, and normal German practice in engine bearings is to use a clearance of 0·001 to 0·0015 times the journal diameter.

There is a very definite need for systematic investigation of all the metals used for bearing purposes, and it would seem that modern engineering developments are accelerating matters appreciably. Take, for example, one of the oldest and most successful of bearing bronzes, namely, that containing 80% copper, 10% tin, 10% lead, so favoured for railway work. This was originally developed in this country about 1870, and no better testimonial to its value can be made than by noting that during the past 60 years little need has arisen for its modification. In fact, indiscriminate additions of other metals are dangerous, unless a full knowledge of the alteration in properties thereby produced are known. For example, the investigations previously mentioned by Pilling and Kihlgren on " Some Effect of Nickels on Bronze Mixtures " indicates that additions of nickel up to 3% to the 80/10/10 bearing bronze results in a progressive improvement in tensile strength, limit of proportionality and yield point with some reduction in ductility.

Whereas this may be of particular value in those applications where maximum strength is required, on the other hand, if maximum toughness is desired by limiting the addition to 0·5% an all-round improvement in properties is obtained as follows :—

Ultimate strength ..	8%	increase.
Yield point	5%	,,
Limit of proportionality	3%	,,
Elongation	22%	,,

In this case the increase in ductility, *in conjunction with improvement in the other properties*, results in a very definite advance, and indicates the future possibilities of close investigation. Such a modification is of practical value for high-duty bearings in this alloy when resistance to " pounding " is desired.

[2] " A study of Lead Bronzes, with Special Reference to Manganese as an Alloying Element." J. Wecker. *Zeitschrift fur Metallkunde*. June, 1935. Vol. 27, pages 149-154.

Nickel-Steel Tube Resists Salt Bath Corrosion

In many heat-treatment departments tanks filled with a solution of sodium nitrate are employed for treating aluminium-alloy parts. The heating of the salt solution is effected by pipes in the bottom of the tanks. Normally, ordinary steel tube, about 5 in. diameter and $\frac{3}{8}$ in. wall thickness, is used for this purpose. Trouble is, however, invariably encountered due to corrosion from the salt solution on the outside of the pipe, and renewals of the pipe are necessary at frequent intervals, about every three or four months. Experiments with wrought-iron pipe have produced little or no difference in service life.

Some time ago, in one plant, 3·5% nickel-steel pipes were installed in two of the sodium nitrate tanks, and it is reported that these have now lasted about two years without a single failure, and appear to be capable of indefinite future service, as the alloy seems to resist oxide penetration at the temperature at which the salt solution is held—approximately 500° C.

Large New Concentrator May Be Erected Near Sudbury

Plans of considerable magnitude are understood to be under consideration by the executives and engineers of the International Nickel Company of Canada, Limited, for the treatment of larger daily tonnages of moderate grade ore. A new concentrator of several thousand tons daily capacity may be built, and the electric shovelling of the top layer of the great Frood orebody down to three hundred feet from the surface is contemplated. The programme may possibly include the concentrating of some ores now being smelted direct, as experience has shown that the furnace equipment, with relatively minor extensions, can take a higher metallic-content feed than is now given it.

The Company may be able, in the course of time, to bring all its orebodies into use, giving the whole mining operation greater flexibility and providing the operating staff at Copper Cliff with closer control of grade at all times. The annual rated capacity of the plant is, at present, 220,000,000 lbs. of nickel, and it is supposed that the programme under consideration contemplates an increased rate of production, although no corresponding increase in copper production capacity is indicated.

At present, the Company mines approximately 15,000 tons daily and concentrates about 12,000 tons per day. The cost of the suggested new concentrator with its complementary plant would run into several millions of dollars, but the programme is so extensive that the expenditure would be spread over more than one year.

Molybdenum in Tool Steels

By W. F. Chubb

The fundamental principles upon which the use of molybdenum in tool steels is based are briefly described, and details are given of the properties obtainable in steels employed for these purposes. Experiences in quantity production, both in this country and America, have been incorporated, together with the results of some original researches on the new molybdenum high-speed cutting steels.

BEFORE dealing in some detail with the physical properties and applications of molybdenum in tool steels, it is necessary to provide a short summary of the metallurgical considerations underlying its use.

An element added to iron-carbon alloys may act in one of three ways. It may (*a*) form a carbide with the existing carbon, (*b*) dissolve completely in the iron or ferrite constituent without combination with carbon, or (*c*) it may combine in part with carbon and dissolve in part in the iron. Molybdenum is an element which falls into the third class of this tabulation, as it is known to form a carbide with existing carbon and to dissolve also in the ferrite constituents. Carbide-forming elements, as such, increase the hardness and the hardening-power of a steel, while those elements which dissolve in the ferrite greatly increase the toughness. Thus it will be clear that suitable additions of molybdenum enhance both properties.

The first property which comes into prominence is that of tensile strength, but in determining the suitability of different steels for particular purposes it is also essential to know what influence each alloy addition will have upon such properties as yield point. In the special purpose under review this is an important factor. Again, in tools for hot working the properties at elevated temperatures require detailed scrutiny, since in such service an otherwise suitable steel may suffer simultaneous corrosion, and because, in addition, it may pass through a brittle range when heating up to its operating temperature. In the latter respect, molybdenum additions in comparatively small amounts are well known to eliminate the tendency to temper brittleness exhibited by certain types of alloy steels, more particularly nickel-chrome steels.

The hardening of molybdenum-bearing steels also presents few problems. Since its presence raises the Ac points somewhat higher hardening temperatures are generally necessary, but since, in addition, the Ar points are lowered, the addition of molybdenum induces greater depths of hardness. Hence, in its propensity towards hardening, molybdenum may be justly described as the most active and potent alloying element, with the exception of carbon, used in steel.

Tool Steels

Although steelmakers' literature does not always reveal the fact, many of the most successful tool steels sold under proprietary names contain proportions of molybdenum to which their superior service performance can be directly traced. Thus, die-block steels, intended for both hot and cold work, have been successfully used for many years, and outstanding service results may be attributed in no small measure to molybdenum additions, even though the actual percentages added may be small in some instances. The effects of molybdenum in producing high-grade die-blocks may therefore be enumerated.

Molybdenum has been found to improve certain necessary characteristics of die steels. In the first place, since the scale formed during forging is not so tenacious, this operation is rendered more economical. Secondly, it will be clear from considerations of constitution, which have been briefly described above, that during subsequent heat-treatment operations less drastic quenching may be employed in order to produce similar hardness conditions. Furthermore, as regards tempering, the known stabilising tendency of molybdenum allows higher tempering temperatures for attaining the desired hardness and, in consequence, at any particular hardness, a tougher die results. Heat-treatment also develops in molybdenum die steels one very important property in which they are superior to other alloy die steels, and it is that greater depths of hardening are obtainable.

It is necessary to emphasise also that less drastic quenching may be employed, and because higher drawing temperatures may be used, a softer die than normally employed can confidently be placed into service. Hence, molybdenum additions provide extremely tough but durable dies, with less danger of checking, spalling, or breaking, and there exists, of course, the additional advantage that these steels do not soften to any appreciable extent in the course of use.

As to machinability, the characteristic of free-cutting which molybdenum additions convey, is to be found in all types of molybdenum die steels. Examples of their applications may therefore be considered.

1. The following composition ranges represent die steels which give consistently high service performance.

Carbon	0·50 to 0·70%
Manganese	0·40 to 0·80%
Silicon	0·15 to 0·25%
Nickel	1·00 to 2·00%
Chromium	0·50 to 1·00%
Molybdenum	0·15 to 0·35%

In the hardened and tempered condition these steels provide a combination of toughness and durability which practically eliminates die breakages. Their resistance to heat is also noteworthy, as this property ensures long runs per die sinking, and the uniformity of hardness throughout a large mass gives an increased number of sinkings without need for rehardening. In this steel, ease of machining, which results from the combined alloy additions, is a noteworthy feature, and machining may also be undertaken readily up to hardness values of 60 scleroscope.

For this type of steel, the recommended heat-treatment consists of a two-stage operation, viz.:

(*a*) Oil-harden at 800/830° C., or cool in air from 845/875° C.

(*b*) Draw to the required hardness, for most purposes at about 540° C.

For annealing, when desired, a temperature of 735/760° C. should be used, and for normalizing a temperature of 845/860° C.

2. The second recommended composition is one containing higher alloy contents. This has the advantage that higher density and toughness are provided, and for this reason, use at comparatively low hardness values is permitted.

Carbon	0·50 to 0·70%
Manganese	0·50 to 0·80%
Silicon	0·15 to 0·25%
Nickel	1·00 to 2·00%
Chromium	0·75 to 1·00%
Molybdenum	0·60 to 0·90%

A die steel of this composition range is especially useful for dies to be employed in hot-working operations, on account of its distinguishing characteristics. In this particular instance, the higher alloy content allows either

air or oil cooling for hardening, and of these two treatments air-cooling is to be preferred, although oil-hardening can be accomplished without risk of cracking. While the temperatures recommended in the first example apply equally well to this second composition, the heat-treatment ranges in this instance show greater latitude. Furthermore, this type of molybdenum steel may be hardened and tempered back to somewhat lower hardness values than is customary for other steels serving the same purpose, since it then combines extreme toughness and durability, a valuable characteristic which still further reduces the possibilities of checking, spalling, or breaking. As is to be expected, the use of a coolant in service, though not imperative, gives longer life to the tool, and for this reason these steels may be employed in forging machines with a water coolant.

From the above considerations, steels within this composition range find extensive employment for upsetting dies, sliding, gripping, and extruding dies, heading dies for punches and rivets, and are also used for punches and plungers, and for both hot and cold shear knives.

3. In the first two examples of molybdenum die steels, it will be seen that relatively high contents of nickel and chromium have been specified. In those instances the function of the molybdenum is largely indirect in augmenting the beneficial effects of these two named elements. That lower alloy contents as regards nickel and chromium can be successfully adopted is demonstrated in the case of a molybdenum steel designed for and specially adapted to use as cold trimming dies and punches. Such a steel contains :

Carbon	0·80 to 0·90%
Manganese	0·25 to 0·45%
Silicon	0·15 to 0·25%
Nickel	0·20 to 0·40%
Chromium	0·50 to 0·70%
Molybdenum	0·15 to 0·25%

In addition to the above-named uses, this steel is also applied to dies for forging in stainless steel, Monel metal, brass, aluminium, copper and similar compositions where the demands are for tools possessing an exceptionally high resistance to abrasion. Further uses to which the steel has been successfully applied are those of coining and straightening dies, and for tools producing drop forging of thin section to be held to close limits. These service requirements demand higher hardness ranges in the steel chosen, and reduced nickel and chromium additions are for this reason specified, but with higher carbon content. It is noteworthy, however, that to enhance the benefits of molybdenum these two latter elements, though present in substantially lower amounts, are not entirely dispensed with. Thus steels of this composition are particularly suitable for deep-drawing dies.

As to heat-treatment, this may consist of the following operations :—

(*a*) Anneal at 800/830° C., and if spheroidising is desired, cool to 700/720° C., and soak.

(*b*) For hardening, quenching should be undertaken from 800/820° C. into the oil-bath, or water-quenching may be employed, in which case a temperature of 780/800° C. should preferably be selected.

In these steels water-cooling for hardening should naturally not be adopted in heat-treating intricate designs.

4. A fourth example of molybdenum steels for dies may be quoted, thus :—

Carbon	0·40 to 0·50%
Manganese	0·35 to 0·55%
Silicon	1·00 to 1·25%
Nickel	1·40 to 1·80%
Chromium	8·00 to 9·00%
Molybdenum	4·00 to 4·25%

The molybdenum has here a predominating influence, and the life of these steels when employed as dies for hot working operations is at least twice that of other comparable alloy compositions. The increased service performance, indeed, completely offsets the somewhat higher cost of these steels. In its softened condition, as obtained by pack annealing, the hardness is 250 to 286, at which values machining to an excellent surface finish may be accomplished. For the above-mentioned uses, the most suitable treatment is that of quenching either in air or in oil from a temperature of 1,120° C. followed by drawing at 510° to 590° C. Thus, at a hardness of C 52 to C 53 on the Rockwell scale, the following properties are obtainable :—

Maximum stress	134 tons/sq. in.
Yield point	125
Elongation in 2 in.	3%
Reduction of area	6%
Izod impact	6 ft. lbs.

The high yield ratio of 93% is a characteristic of this type of molybdenum steel.

Molybdenum High-speed Steels

Since the advent of tungsten high-speed steels numerous modifications have been attempted for enhancing the cutting properties. The super grades of high-speed steel have met with varying success, and, indeed, many of the compositions advocated, as well as the performances obtained in machining operations, have been the subject of some interesting discussions in past years.

It is now established, however, that in additions up to 3% molybdenum can replace tungsten in part, and at the same time benefit steel as a combined toughening agent and hardness retainer in the more common grades of tool steels. Thus, in tungsten steels employed for chisels, the influence of these molybdenum additions is that of widening the hardening range, and as such it is of considerable value. It has, moreover, been demonstrated that in additions up to a limit of 10% molybdenum can act in complete replacement of tungsten in high-speed cutting steels, and the materials thus made available are claimed to exhibit the property of red-hardness in an exceptional degree. Such steels are now manufacturered to the following composition limits :—

Carbon	0·65 to 0·75%
Manganese	0·15 to 0·30%
Silicon	0·15 to 0·30%
Chromium	3·25 to 3·75%
Molybdenum	9·25 to 9·75%
Vanadium	1·15 to 1·35%

In this composition, the only radical departure from the normal high-speed steel composition of the 18-4-1 type is clearly the replacement of tungsten by its equivalent of molybdenum. Such steels are structurally sound, molybdenum recovery being, if anything, better than that of standard tungsten compositions. During rolling and forging operations, no greater decarburisation may be expected to occur than with the high tungsten steels. Also, during hardening similar troubles should not occur, but may, of course, be guarded against by the use of atmosphere-controlled furnaces.

Molybdenum high-speed steels may also be annealed to a very refined fracture, and in this condition they possess a comparatively low Brinell hardness of 196 to 212. Furthermore, in the hardened state the fracture is of a refined and silky nature, corresponding to a Rockwell value of 62 to 63 on the "C" scale. These values are slightly lower than is commonly attained with the 18% tungsten high-speed steel, but with no detriment, however, to the important property of hardness-retention at elevated temperatures.

It has been stated that during forging and hardening operations, molybdenum high-speed steels are prone to loss of alloy content by volatilization. If this statement means loss of molybdenum by direct volatilisation, this is clearly impossible, and a little thought will show that, as with other high alloy steels, the only possible loss of alloy content is that at the surface due to oxidation by scaling.

The desirable cutting qualities and other characteristics of molybdenum high-speed steels are therefore worthy of extended trials by those potential users who have not yet considered their applications to machining purposes.

New Industrial Map of the U.S.S.R.

By A Special Correspondent

The economic map of the U.S.S.R. has been radically changed in the last twenty years. The widespread industrialisation of the formerly backward areas, rich in raw materials and power resources, and the economic development of the various regions are the main features contributing to this change and in this article the development is reviewed.

THE proverbial backwardness of pre-revolutionary Russia was still further aggravated by the irrational arrangement of its economic geography. Not only were the immense natural resources contained in the depths of the earth, the forests and rivers, little utilised, the natural wealth of the country was hardly studied at all. The more accessible of the resources were uneconomically exploited. Nearly the whole of the oil industry was concentrated in Baku, the coal industry in the Donetz Basin, ferrous metallurgy in the South of the Ukraine and partly in the backward Urals, two-thirds of all the manufacturing industries in the country were concentrated in a few provinces of the Centre, which possessed neither fuel nor raw materials. The rest of Russia—Siberia, Central Asia, the Caucasus, the North—served as appendages for the supply of raw material to the mother country.

The twenty years of construction since the Revolution, particularly during the First and Second Five-Year Plans, have wiped out the former backwardness in industry, agriculture, culture and defence. From a backward agrarian country the Soviet Union has been converted into a great industrial power.

In addition to the general development the two Five-Year Plans have radically changed the economic map of the U.S.S.R. Numerous natural resources have been discovered and prospected in the country; her forests and rivers have been studied; new branches of industry have been created; vast new territories have been opened up for development; the biggest canals in the world and giant hydro-electric power stations have been built; new trunk railways and motor roads have been constructed; airways have been established; the sea route through the icefields of northern seas has been mastered.

The volume of industrial production of the U.S.S.R. at the beginning of 1937 exceeded that of the pre-war production of Russia by more than sevenfold. Especially marked has been the growth of heavy industry and its leading branches—the fuel industry, metallurgy, the engineering industries, the generation of electric energy.

The intensity of this growth has been due to the fact that heavy industry was distributed anew throughout the territory of the Union, and in its wake, light and food industries sprung up at the bases of supply of raw materials and the consuming centres. The geographic distribution of agriculture, too, was changed.

The opening up of a second coal and metallurgical base in the East, the widespread industrialisation of the formerly backward borderlands, rich in raw materials and power resources, the economic development of the national republics and regions, the all-round strengthening of the country's means of defence—such are the main directions which have been followed in redrawing the economic map of the U.S.S.R.

The central idea of the newly-created second coal and metallurgical base in the East has been the linking up of the Ural ores and Kuznetsk coal. On the biggest of the Ural deposits of iron ore—Magnitny Mountain—has been built the most powerful metallurgical combine in Europe; this combine uses Kuznetsk coal. At the other end of the Kuznetsk coal base has been built the huge Stalinsk Metallurgical Works, which uses Magnitogorsk ore.

The Urals possess such a combination of natural resources as is to be found in no other country. But until the Revolution they lay dormant. The metallurgical and coal enterprises that existed in the Urals were small-scale, primitive concerns. To-day, from the remote North—Amderma and Vorkuta—to Blyava and Orsk (South Urals), throughout the whole of the Urals, stretches a chain of reconstructed and newly-built powerful industrial enterprises of ferrous and non-ferrous metallurgy, coal, oil, chemical, engineering, timber and paper-making industries, as well as huge electric power plants. The Sverdlovsk and Chelyabinsk districts are among the most industrialised regions in the country.

The Urals now produce over 2½ million tons of pig iron, i.e., about two-thirds of the total volume of pig iron produced in pre-revolutionary Russia. The reconstructed and newly-built copper flotation works produce two-thirds of the total output of copper in the U.S.S.R. On the basis of the by-products of metallurgical production and the potassium salts of Solikamsk has been created a huge chemical industry; the output of machinery in the Urals constitutes 8% of the total production in the Union. The output of coal in the Urals has increased ninefold.

The Kuznetsk coal basin, which is fast becoming a second Donetz Basin, is expected to produce in 1937 about 20 million tons of coal. Kuznetsk coal is used not only by the Urals and Central Asia, where there is insufficient fuel, but by many European parts of the Union. In the vicinity of the Prokopievsk coal centre and the Stalinsk metallurgical centre have sprung up new chemical and engineering centres, at Kemerovo, Novosibirsk and other places.

Soviet Kazakhstan is being converted into an important base of non-ferrous metallurgy. In 1937 the biggest copper flotation combine in Europe, built at Kounrad, near Lake Balkhash, is to turn out its first batch of copper. A commencement will be made in working the powerful deposits of Jezkazgan. Old Ridder has been reconstructed. Vast deposits of non-ferrous ores have been discovered in the Altais; Kazakhstan is expected to produce more than two-thirds of the total output of lead in the U.S.S.R. and over a tenth of the copper. But Kazakhstan has also become important as the third coal producing centre of the Union. The Karaganda coal deposits, discovered and put into exploitation since the Revolution, produce more than 4 million tons of coal and act as an important base of fuel supply for the Urals. Kazakhstan, too, is rich in oil (Emba) and phosphorites (Aktyubinsk), on the basis of which a big combine for the production of nitrogenous fertilizers has been built. The extended production of agricultural raw materials in the republic (cotton, hides, wheat, etc.) has made possible the creation of powerful light and food industries.

Bashkiria has become an important oil producing centre (Ishimbayevo) and a centre for the production of machinery.

With the creation of a second Soviet coal and metallurgical base (the Ural-Kuznetsk Combine), in the remaining regions of the country—in the East, the Volga region, the backward national regions in Central Asia, the Transcaucasus and other districts, which formerly had no industries of their own—there have simultaneously

been created a number of industrial centres of great importance to the further development of the Union as a whole.

In the Far East has been created a new engineering and growing metallurgical centre—the town of Komsomolsk-on-Amur; a coal industry has been developed at Suchan, Artem and Kivda; engineering industries have grown up at Vladivostok, a cement industry at Spassk, oil refining and engineering industries at Khabarovsk, etc. Engineering centres have been created at Ulan-Ude (the capital of Buryat-Mongolia), at Irkutsk, Krasnoyarsk; Cheremkhovo and East Siberia have become important coal-producing centres.

The Central Asiatic republics, which used formerly to be mere suppliers of raw cotton and silk cocoons for the factories of the Centre, have now completely changed their character. Cotton growing has been entirely reorganised. New irrigation systems irrigate the fields, and alongside the extension of cotton growing and sericulture, numerous other industries have sprung up.

Agricultural machinery for the cotton fields is produced by the new engineering works at Tashkent. Kirghizia has become the principal coal base of Central Asia, her output of coal having risen from 103,000 tons in 1913 to 1,200,000 tons in 1936. An oil industry has sprung up in Turkmenisten. An oil industry is also growing up in Uzbekistan. In the Kara-Kum desert in Gaurdag the production of sulphur has been commenced. Mirabilite is being worked at Kara-Bugaz-Gol; deposits of non-ferrous polymetallic ores and rare metals have been discovered since the Revolution in Uzbekistan, Tajikistan and Kirghizia. On the supplies of raw materials in the Central Asiatic republics numerous light industries have been organised both of local and All-Union importance. The textile combine built at Tashkent is one of the biggest textile enterprises in the Union. Other textile enterprises have been built in Charjuy, Stalinabad, Fergana, etc.

On the River Chirchik, near Tashkent, has been built a big power and chemical combine, comprising an electric-generating station with a capacity of 250,000 kw., and a nitrogenous fertiliser combine to supply fertilisers for the cotton fields.

The face of the Transcaucasus has completely changed.

The output of oil in Azerbaijan has been trebled. Engineering and chemical industries have sprung up at Baku. A new textile centre has been created in Kirov-Abad. The first big hydro-electric power station is being built on the Terter. Azerbaijan has become the principal base of Egyptian cotton growing and is becoming the second largest centre for tea and citrous crops. Georgia has been covered with a network of hydro-electric power stations; the working of the Chiatury manganese ores has been reconstructed; a plant for the production of ferro-alloys has been built at Djugeli. Chemical, engineering and light industries are springing up in the republic of Georgia, which is the principal grower of citrous and tea crops in the Union.

In the principal Volga towns—Kazan, Saratov, Kuibyshev, Stalingrad, etc.—have been created new engineering centres, shipbuilding yards, tractor works, railway carriage works, and plants for the manufacture of machine tools. Local fuel, slate, is being worked in Savelyevka and Kashpira, sulphur is being worked in Alexeyevka, oil wells are being drilled in the new oil regions near Syzran. Powerful hydro-electric stations are being built on the Volga at Rybinsk; preparations are being made for the construction of the world's biggest hydro-electric power stations on the Samara bend of the Volga, at Kuibyshev, the capacity of which will exceed by 2½ times the capacity of the electric power stations of pre-revolutionary Russia. The building of these two stations will also solve the great problem of irrigation in the Volga territory.

The Ukraine, the republic richest in natural resources and fertility in the Union, has become a powerfully industrialised country. The reconstructed Donetz basin now produces four times as much coal as used to be produced there before the war—54% of the entire output of coal in the Union. The reconstructed and newly built giant ferrous metallurgical works produce four times as much metal as before the war. The newly created engineering industries of the Ukraine turn out more than a tenth of the output of machinery in the Union. In the Ukraine, has been developed a powerful chemical industry; the most powerful electric-power stations in the Union, headed by the Dniepr Hydro Electric Power Station, have been built there.

Some of the greatest changes have taken place in the economic geography of the European part of the U.S.S.R. The old industrial regions in the Centre and the first coal and metallurgical base of the Union—the Ukraine—because of the skilled workers and engineers they possessed, played an enormous part in the development of the new regions.

Parallel with the development of new industrial districts, the old industrial regions of the U.S.S.R. have also developed rapidly.

The "textile" Moscow Province has become a centre for the engineering industry (producing a fifth of the total output of machinery in the U.S.S.R.), for a powerful chemical industry (at Stalinogorsk, Voskressensk, etc.), and metallurgical industry, producing quality metals. The output of coal in the Moscow basin has increased from 300,000 tons in 1913 to 8,800,000 tons in 1937. Peat, too, has become an important factor in the fuel supply of the district.

The Ivanovo and Yaroslavl districts, which used to produce linen textiles, have become centres for the production of chemicals and machinery. The Leningrad Provinces has grown into a centre for specialised machine-building and an electro-technical industry. The Gorky district, with its giant Molotov automobile works, has become a powerful engineering centre. The old wood-working enterprises, paper mills and match factories have been reconstructed and new engineering and chemical industries have been created. On the basis of local supplies of raw materials, linen textile industries have been established in White Russia, the Yaroslavl Province, etc.

In the North—the Archangel Province, Karelia and Komy—have been developed, timber and wood pulp, industries; a coal industry is growing up in the open coal basin on the Pechora, an oil industry at Ukhta and Izhma, and powerful chemical and food industries on the Kola Peninsula.

Such, briefly, are the main features of the new economic map of the U.S.S.R. In accordance with the national policy of the Soviet regime, the once backward national minority republics and regions of the Union have shared in the general economic and cultural growth. The rational distribution of the industries throughout the entire territory of the country is a pledge of still greater future development.

Stainless Steel Valves Resist Sulphite Corrosion

FEW manufacturing processes demand more resistance to corrosion in the containing vessels than the sulphite process of papermaking. Hence, most sulphite mills are adopting acid-resisting chromium-nickel stainless-steel valves, fittings and piping. In one instance, in particular, the castings for these valves are made in a type of steel containing 3% of molybdenum in addition to the normal 18% chromium and 8% nickel content.

This latter steel has proved ideal for use in sulphurous acids and hot cooking liquors such as are regularly handled by digester valves in paper mills. In the design advantage is taken of the tensile strength as well as the corrosion-resistance properties of this steel to reduce wall and flange thicknesses, with a view to reducing costs.

Mechanical Properties of Copper-Tin Alloys at Elevated Temperatures

The results of an investigation to establish a reliable means of comparison between four standard tin bronzes and other bronzes are discussed.

ALTHOUGH the binary tin bronzes are among the best known copper alloys, little data is available regarding their mechanical properties at elevated temperatures. For this reason a systematic investigation has been undertaken by C. G. Goetzel to establish a reliable means of comparison between four standard tin bronzes and other bronzes, and to construct a more suitable base line for study of the more complex alloys in which tin is replaced, partly or completely, by aluminium, silicon, manganese, zinc, or lead.

The materials studied were binary bronzes of copper-tin ratios 94/6, 90/10, 86/14 and 80/20, and were examined in the cast condition and after annealing, the 94/6 bronze, nominally a rolled material, was included merely for comparison purposes. The four bronzes were carefully prepared from virgin metals, double melted, deoxidised with phosphorus, and cast in dry sand moulds at a temperature of 1,260° C. in test-bars 15 in. long by 1 in. diameter. From each test-piece two tensile test-bars were cut (one for heat-treatment), and one Brinell hardness test-piece. The test-pieces for heat-treatment were then annealed in an electric furnace, the 94/6 alloy being annealed at 900° C. for 30 mins., and the other alloys at 780° C. for 300, 360, and 420 mins., respectively, after which they were allowed to cool slowly in the furnaces.

Data was then secured on the elastic limit, proportional limit, yield strength, tensile strength, elongation, etc., at room temperature, and at 100, 200, 300, 400, and 500° C. The Brinell hardness was measured at room temperature and at 100, 200, and 300° C. Tensile tests at ordinary and elevated temperature were carried out according to the standard methods of the American Society for Testing Materials, except for variations in the size of the test-bars and the testing temperatures. Brinell tests were made with a 10 mm. ball and a testing time of 30 secs. The hardness of each of the four alloys was determined with a load of 500 kg. on each of the samples as cast, and on an annealed sample. On the 94/6 bronze additional tests on cast samples were made with test loads of 1,000 and 1,500 kg., and on the other three bronzes with test loads of 1,000, 1,500 and 3,000 kg. For Brinell tests at elevated temperatures the ball was placed between two samples to be tested with the test surfaces facing each other, which were placed in an electric furnace, and the pressure applied to the samples from both sides using steel cylinders extending from the furnace and centred by means of a parallel faced, heavy steel guide. The mechanical properties of the four alloys are given in Table I. The fractures of the tensile tests were examined, and an attempt made to co-relate these with micro-structures of the specimens.

This series of investigations not only offers a comparison of the properties of each of the separate alloys in the cast as against the annealed form at ordinary and elevated temperatures, but also a comparison of the various alloys with each other. The rolling bronze 94/6 at ordinary and elevated temperatures shows no important difference in the cast and annealed conditions, and the 90/10 bronze behaves similarly. The values for the yield point, for the modulus of elasticity, and for the Brinell hardness of the 86/14 bronze at room temperature are higher than the corresponding values in the annealed condition. With rising temperatures, the physical properties of both cast and annealed specimens decrease in value with the exception of the elongation and reduction of area in the cast state.

The 80/10 alloys showed no difference of practical importance between the cast and annealed conditions at all temperatures.

TABLE I.

MECHANICAL PROPERTIES OF COPPER-TIN BRONZES.

Temperature ° C... ..		20.	100.	200.	300.	400.	500.
94/6	Yield point, tons per sq. in. ..	6·9	5·7	5·1	5·1	5·1	4·4
	Ultimate stress, tons per sq. in...	15·9	15·7	14·0	10·2	6·4	7·0
	Elongation, % ..	33	32	22	16	3	3
	Brinell Hardness ..	52	51	47	44	—	—
90/10	Yield point, tons per sq. in. ..	9·0	6·4	6·4	7·0	6·4	5·1
	Ultimate stress, tons per sq. in...	20·4	17·1	17·1	11·4	9·0	8·0
	Elongation, % ..	45	39	32	10	6	6
	Brinell Hardness ..	62	60	59	57	—	—
86/14	Yield point, tons per sq. in.	9·5	8·0	8·0	7·0	7·0	4·4
	Ultimate stress, tons per sq. in...	14·6	14·6	14·0	10·8	9·0	8·0
	Elongation, % ..	7	8	9	7	7	8
	Brinell Hardness ..	79	77	74	69	—	—
80/20	Yield point, tons per sq. in. ..	—	—	11·6	10·1	7·0	2·6
	Ultimate stress, tons per sq. in...	12·1	12·1	12·1	12·1	10·2	5·1
	Elongation, % ..	—	—	—	0·5	8	15
	Brinell Hardness ..	120	119	110	98	—	—

As a result of these investigations, it is evident that under prevailing favourable thermal conditions in the process of solidification and of cooling of the 94/6 and 90/10 alloys, a type of grain structure is attained which, to the greatest possible extent, approaches the ideal homogeneous state, at least in accordance with the earlier type of copper-tin diagram. With alloys similar to cast 86/14 bronze it is a different matter, where the existing number of crystals resulting from solidification and cooling seems to be too great to be balanced during these changes, so that a subsequent compensating annealing treatment must have an important effect. In the case of the 80/20 alloy, the normal amount of brittle Cu_3SN present is so great that a compensating annealing can hardly influence the mechanical properties. The relative lack of response of all but the 86/14 alloy to annealing is therefore of some importance.

The characteristic properties of the cast and annealed specimens of the tested alloys, such as the 2% yield strength, the tensile strength, the elongation, and the Brinell hardness, should be compared at room temperature because they are the properties ordinarily recorded. Comparing the 94/6 (cast and annealed), 90/10 (cast and annealed), and 86/14 (annealed) alloys with one another, on one hand, and comparing the 86/14 (cast), and the 80/20 (cast and annealed) alloys with each other, on the other

Metals and Alloys, 1937, Vol. 8, pp. 231-234 and 245-249.

hand, reveals only one important difference between the two types of materials, the difference being in the Brinell hardness which varies from 50 to 67 in the former, and from 79 to 120 in the latter.

The investigations also show that with expert casting technique maximum values of the mechanical properties of the cast binary bronzes can be obtained, which at present are not generally obtained. They also determine the physical properties of 96/4, 90/10, 86/14, and 80/20 tin bronzes in the cast and annealed form at elevated temperatures, and show that the binary tin bronzes of the cast type can be stressed for short periods without danger up to temperatures of 200 to 300° C. As the investigations were made only as short-time tests at high temperatures, the results cannot be interpreted as any indication of the relative creep strengths of the alloys.

Hiduminium RR77

A new alloy in the Hiduminium series, developed after long research, possesses unique properties. Not only does it possess high strength, but it has excellent corrosion resistance, ductility, fatigue resistance, electrical and thermal conductivity. It has been developed for use in highly stressed parts.

RAPID progress is being made in the development of alloys of high strength designed to solve the many problems associated with speed, efficiency and durability with which designers and engineers in all progressive industries are confronted in modern engineering. All sections of metallurgy are contributing in this forward movement, but the need for high strength to weight ratios has given an added impetus to the light alloys and the series of aluminium alloys, discovered by Messrs. Rolls Royce Ltd. and developed by Messrs. High Duty Alloys Ltd., has contributed in a large measure, to modern needs. This series of alloys, marketed under the trade name Hiduminium, comprises a number of alloys each of which is designed for a specific type of work and a new alloy has recently been added to the series, known as Hiduminium RR77.

GENERAL MECHANICAL PROPERTIES.

Condition	In Tension		In Compression				
	0·1% Proof stress t./sq. in.	Ultimate stress t./sq. in.	Elongation %	0·1% Proof stress t./sq. in.	0·5% Proof stress t./sq. in.	Brinell hardness No.	Endurance limit at 20×10^6 cycles
Solution treated and artificially aged	28–33	33–38	16–10	27–30	32–36	160–180	±12.5–13.0
Solution treated and naturally aged	18–21	29–32	21–16	17–21	22–25	130–140	—
Annealed	4–8	12–14	20–14	4–8	7–9	45–65	—

HIDUMINIUM RR77.
PHYSICAL PROPERTIES.

Specific Gravity	2·80
Specific Weight, lb. per sq. in.	0·101
Co-efficient of Thermal Expansion—	
20—100° C.	20×10^{-6}
20—200° C.	22×10^{-6}
20—300° C.	23×10^{-6}
20—400° C.	25×10^{-6}
Electrical Conductivity—	
Solution treated and artificially aged, Reciprocal ohms. per Cm³	200,100
Solution treated and naturally aged, " " " "	185,800
Annealed, " " " "	261,000
Thermal Conductivity (Calculated)—	
Solution treated and artificially aged—	
In C.G.S. units	0·340
As a percentage of copper	37
Solution treated and naturally aged—	
In C.G.S. units	0·320
As a percentage of copper	34
Annealed—	
In C.G.S. units	0·421
As a percentage of copper	44·5
Young's Modulus (E.), lb. per sq. in.	$10·0 \times 10^{-6}$

This new alloy is an aluminium base alloy with a specific gravity of 2·8; it has been developed for use in highly stressed parts and is claimed to be unsurpassed on a yield strength to weight ratio by any other material so far available for the purpose. The alloy represents the results of prolonged research for an alloy possessing unique properties, and, in addition to high strength, it has excellent corrosion resistance, ductility, fatigue resistance, electrical and thermal conductivity. Its physical and mechanical properties are given in the accompanying tables.

For the hot working, and to a lesser extent, for the heat-treatment of this alloy, rather different conditions hold as compared with other alloys in the series. A large amount of work, however, has been carried out on these problems and a thorough knowledge has been acquired of the peculiarities of the alloy in these respects, it has, in fact, been found that parts fabricated from this alloy, by the special operations which have been evolved for their production, possess greater uniformity of properties in different sections and in different directions of flow than it has been possible to obtain with the other wrought light alloys.

Machining and cold forming present no difficulties as the alloy responds readily to those operations used with other high strength alloys. It is available in most forms, such as pressings, extruded and drawn sections, and sheet, which can be supplied with various heat-treatments, giving a wide range of mechanical properties. It can be anodised by the usual processes, and with or without this treatment it presents an attractive finish.

This alloy is manufactured by High Duty Alloys, Slough. Extruded bar, sections and drawn tubes in the alloy are produced by the Reynolds Tube Co., Birmingham, while sheet or strip are rolled by the Reynolds Rolling Mills Ltd., Birmingham.

Henry Wiggin's Agents' Meeting

REPRESENTATIVES of twelve European countries met at the recent annual sales convention of Henry Wiggin and Co. Ltd., of Birmingham. A full programme was arranged which included not only an inspection of the company's plants at Birmingham, but also the Clydach refinery of the Mond Nickel Co. Ltd. A series of discussions also took place on the applications of nickel, Monel and Inconel, the range and scope of the Wiggin chemical salts, the development of depolarised and other anodes, and on the work of the Bureau of Information on Nickel.

Reference was made to the excellent resistance of Monel to hydrochloric, sulphuric and hydrofluoric acids at the concentrations and temperatures used in pickling. Other advantages that received attention were its immunity from wasting, also its strength and toughness which enable crates to be made that are notable not only for their rigidity but also for their lightness. A point that still further enhances the rigidity and durability of Monel crates is that, due to the recent development of improved welding rods, welding may be substituted for riveted joints.

On the subject of depolarised anodes the increasing demand for speed in plating was referred to and, in this connection, depolarised anodes are of particular value, for they work efficiently at high current densities, thus enabling a higher output to be maintained. Amongst the other advantages of this type of anode, may be mentioned the fact that it overcomes passivity which occurs with rolled anodes when used at high current densities; also, it dissolves evenly and cleanly, maintaining its metallic appearance throughout its working life.

Social activities included a visit to Stratford-on-Avon and several interesting functions.

Reviews of Current Literature

Arc-welding Handbook

THE successful application of arc-welding to various branches of industry has been responsible for considerable modification in the technique of structural fabrication. So great is the progress in the application of welding, that it is now regarded as a special industry, and efforts have been made to train its personnel so that the processes adopted can be used to the best advantage. This handbook will supplement instruction the operator of the arc-welding process may have received, and certainly will enable him to understand more fully the various methods employed in this form of welding.

Electric arc-welding has been growing in importance for many years and its interest is no longer confined to operators and engineers of large undertakings, but has spread to the smaller workshops and this book is designed so that those engaged in this process of welding may be able to utilise the results of the latest research in improving and simplifying their work. Owners of small workshops will find that the book contains much valuable information and advice.

The handbook describes the progress of arc-welding, as well as machines and accessories, sufficiently to enable practical men to select and operate equipment suitable for the particular operations. It gives a detailed consideration of electrodes, particularly regarding their welding characteristics and relative costs, as well as their influence on the weld itself. The most comprehensive section is that which deals with the welding of steel. This section opens with a short description of the parent material, followed by a consideration of the fundamental types of welded joints. Included is a résumé of practical arc-welding, i.e., the preparation and setting up of the work, connecting up, optimum current and electrode diameter, penetration, effect of arc length on the nature of the run produced, magnetic blowing of the arc, manipulation of the electrode and the heating effect.

Other sections deal with the hot- and cold-welding of cast-iron and the welding of non-ferrous metals. It is noteworthy that considerable attention is given to the welding of aluminium and its alloys, to copper and its alloys, and also to nickel and nickel alloys. The book concludes with a section dealing with various tests for welded joints. The text matter is presented in a interesting as well as informative manner and the welding engineer as well as the operator will find this book invaluable as an aid to the successful application of arc-welding.

By KARL MELLER; translated by J. E. WEBB GINGER, D.F.H., A.M.I.E.E., V.D.I., published by Hutchinson's Scientific and Technical Publications, Paternoster Row, London, E.C.4. Price, 8s. 6d.

Transactions A.I.M.E. (1937) Vol. 124

Institute of Metals Division

THIS volume contains twenty-two papers and discussions presented before the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers at meetings held at Cleveland in October, 1936, and New York in February, 1937. In addition it contains the Institute of Metals Lecture on the subject of "Refractories" by Professor R. S. Halton, of Cambridge University, and a lecturer on "The Stereographic Projection" by Dr. Charles S. Barrett, of the Metals Research Laboratory, Carnegie Institute of Technology.

Many of the papers in this volume are of fundamental importance and, with the papers published in the ten previous volumes, constitute a reference library which can be regarded as indispensable to physical metallurgists. Mr. J. C. Mertz and Professor C. H. Mathewson review the work previously done on the solubilites of phosphorus, arsenic, antimony and bismuth in copper and, in view of the uncertainties thus made apparent, present new X-ray data obtained with the first three numbers of this group. Further work on the equilibrium relations in aluminium-base alloys is presented in another paper by Dr. William L. Fink and Mr. L. A. Willey, the object being to increase knowledge of the aluminium corner of the more important ternary systems. Mr. William Mikielas and Professors Lars Thomassen and Clair Upthegrove present the results of an investigation on the equilibrium relations in the nickel-tin system.

A paper by Mr. Morris Cohen establishes the existence of pre-precipitation phenomena in a silver-copper alloy. The results of investigations lead to the belief that knot formation plays an important part in the fundamental ageing mechanism of silver-copper alloys. An important contribution by Dr. William L. Fink and Dr. D. W. Smith deals with the age-hardening of aluminium-magnesium alloy; while Mr. R. H. Harrington discusses precipitation-hardening and double ageing. Notes on etching and microscopical identification of the phases present in the copper-zinc system are given by Mr. J. L. Rodda. The report of an interesting investigation is that by Mr. C. G. Goelzel which deals with an investigation to determine whether silver alloys could be used for ring groove inserts in light metal pistons, instead of high-expansion austenitic ferro-nickel alloys. Lead coating of steel is discussed by Mr. J. L. Bray who concludes that steel or iron can be coated with lead by using zinc as a binding alloy if the temperature and composition of the bath are held within narrow limits.

Among other papers of fundamental importance is one by Mr. R. M. Brick and Professor Arthur Phillips on the diffusion of copper and magnesium into aluminium, which has been studied at varying temperatures, employing specimens where a eutectic of the solute and solvent metals was brought in clean and intimate contact with pure aluminium; but only brief reference can be made here to the valuable work presented in these various papers. This volume, like previous volumes of the Transactions, is well illustrated and produced.

Published by the American Institute of Mining and Metallurgical Engineers, 29 West 39th Street, New York, N.Y., U.S.A. Price $5·00 net.

Aluminium in Architecture and Decorating

THIS is a very informative publication, presenting a selection of examples of aluminium and its alloys used for architectural and decorative purposes, indicating a considerable diversity of purposes and the different styles and treatments that are possible for the large number of forms in which these metals can be used.

The 49 illustrations show how this versatile metal is used, in the form of sheet metal, extruded sections, castings, tubes and forgings. The various surface finishes—polished, frosted, scratch brushed, anodised finish and coloured effects possible through dyed anodysing. This latter process gives a brilliant transparent colour that will not flake, blister or chip.

The present range of aluminium alloys provides a wide diversity of characteristics, the alloys retaining the attractive colour and high resistance to corrosion of the parent metal. All of the alloys available should not, however, be used indiscriminately for architectural work, the company always being willing to give advice on the choice of an alloy for a specific application,

As sheet aluminium can be spun, pressed or hand beaten, withstanding considerable deformation without tendency to split, it can be used for panels, doors, lift enclosures and similar purposes, or flat panels or simple constructional applications can be catered for by aluminium faced plywood.

One of the most widely applicable forms in which aluminium can be used in architecture is that of extruded sections. The metal and its alloys can be extruded with

great facility and long straight lengths of almost any section can be obtained. Nearly 4,000 dies are available, giving a wide choice, in addition to the fact that special shapes can be provided at a reasonable cost.

Extruded sections are used for windows, most often these are anodised; this is one of the applications where the lightness of aluminium is a decided advantage. Another use is for show cases and display fittings, whilst hand rails and balustrades are also made from the extruded section. Pure aluminium is most commonly used in the latter application. If additional strength is required this can be obtained either by concealing an iron or steel support in a recess in the aluminium section or by using one of the harder alloys such as Birmabright.

Hand formed grilles can be made from flat, round or square bars of pure aluminium. These can be formed cold, but there is no objection to heating for easier working of more intricate shapes, as such heating to temperatures of 300–400° C. does not harm the metal. Here, too, rivetting or welding can be used in assembly, quite easily and without detriment to the qualities or appearance of the aluminium or alloy.

Alloys are used more frequently than pure aluminium for castings, and it should be remembered that only a limited number of these will anodise successfully. Grille work, hand rail supports, decorative plaques, seat pilasters, etc., are made as castings, but care has to be exercised in the selection of alloys as some anodise with a dark colour.

The book shows the application of aluminium to windows and other aspects of modern buildings including canopies, entrance doors, shop fronts, marquise and other metal work, roof garden railings, ornamental grilles, balustrades, wall brackets, shop service fittings, screen framing, lift enclosures, skirtings and pilasters, clock hands, post office grilles, inlaid strip ornamentation, decorative panels, alcove gates, brilliantly coloured anodised aluminium tiles for ornamentation effects, escalator casings, tubes and facings for exhibition stand fittings and displays, the application of anodised aluminium faced plywood ("Plymax"), and two very effective air conditioning grilles in aluminium alloy, fret cut by hand and with applied motifs.

Such accessories as bolts, screws and rivets in aluminium can be supplied, thus enlarging the scope of the architect and designer.

Published by the British Aluminium Co. Ltd., Adelaide House, London, W.C.4.

Sands, Clays and Minerals

In the current issue of the above publication, Mr. A. L. Curtis, the editor, stresses the need for a survey of the mineral wealth of the British Empire. We need, he writes, more complete knowledge of our Imperial mineral resources, and a co-ordinated plan for winning, transporting and marketing them. An Imperial survey of this character is beyond the powers of private enterprise; it would necessitate the co-operation of industry and the Government, metallurgist and explorer, geologist and economist to perform such a task. Mr. Curtis outlines a series of provisions such a survey should include, and states that the condition of our Empire minerals calls for great and sustained action of this character.

The issue contains many interesting and informative articles on subjects which include the mining and mineral resources of Kenya Colony; beryllium and its alloy; undeveloped mineral resources of Cornwall; mining in Nova Scotia; the preparation and marketing of coal; the mineral resources and potentialities of Uganda; minerals of Southern Rhodesia; and several other useful contributions.

The Lincoln Arc-welding Foundation

A MEMORANDUM has been issued by the James F. Lincoln Arc-Welding Foundation (Cleveland, Ohio) to explain, and explain clearly, the real object which has inspired the Award Programme of the Foundation.

The executives of the Foundation have the firm belief that the use of arc-welding and of arc-welded construction can save much money, performing a job as good as or even better than by previous methods, and at less cost. The reason why arc-welding is not more generally adopted, in the opinion of the Foundation, is that people just do not believe these savings can be achieved. It is claimed that if manufacturers and constructors really did believe that they would save from 10% to 50% of their present cost by using arc-welded construction, they would certainly use it, and would find ways and means to overcome the fact that their engineer did not know how to design for arc-welding, the opposition of their salesmen and the other arguments that are cited against the use of arc welding generally. In other words, the Foundation point to a lack of knowledge and subsequent lack of appreciation, also to a certain degree of prejudice possibly based upon those related factors. Their object is to get the men at the head of companies to make a study of their products or methods of construction, to find out the facts for themselves, or to appoint one or more people in their organisation to make such a study of arc-welding as applied to their own construction, then to get this in the form of a report which could then be submitted to the Foundation as a paper.

The man who submits a paper can expect a reasonable reward for this trouble. Some 400 will receive awards ranging from $100 to $13,700, and the reasonable expectancy of that recognition by his own management which will give him a better job. The management will get the benefit of seeing how savings can be effected by arc-welding—its application, it is stated, covering probably 90% of cases. Industry as a whole will stand to gain considerably. It is estimated that there is still 85% of the firms in the iron and steel industry and manufacturing concerns who would benefit considerably by the adoption of arc-welding. And so we see that the basic object of the Foundation is to develop that 85% who are not using arc-welding.

It is confidently believed that companies whose men prepare papers will benefit greatly through savings which those men will bring out and develop further in new designs.

Dr. L. B. Hunt, M.Sc., A.M.I.A.E., for the past two and a half years editor of *The Metal Industry*, has resigned to take up an appointment as Technical Manager of Mallory Metallurgical Products Ltd. This company has recently erected a plant at Croydon, and will produce and market in this country and in Europe the range of hard high-conductivity alloys developed by P. R. Mallory and Co. Inc., Indianopolis.

A Stainless Steel Bell for H.M.S. Sheffield

In a speech at the recent general meeting of Hadfield's Ltd., the chairman of the company, Sir Robert Hadfield, Bt., F.R.S., referred to a ship's bell made for H.M.S. *Sheffield*. For the first time in history, said Sir Robert, one of His Majesty's ships is to bear the name of Sheffield, and as proud citizens we are all interested in maintaining a close fellowship with the officers and men who serve in her. Many of the Sheffield companies are co-operating with the City Council in providing tangible evidence of the city's interest in her welfare, and we are honoured in being permitted to present the ship's bell as our contribution.

The bell, cast in our foundry, was made from a pattern lent to us by Messrs. Mears and Stainbank, of Whitechapel, who were good enough also to permit Mr. MacDonald to give expert guidance in the "tuning" of the bell. Era C.R. steel, specially resistant to corrosion, has been used throughout. Under Admiralty regulations it is not permitted to a company to make presentations to ships of His Majesty's fleet, and it has therefore fallen to Sir Robert, as the representative of his colleagues on the board, the staff and workmen of Hadfields Ltd., to act as donor.

Controlled Atmosphere Annealing

By E. C. J. Marsh, B.Sc., A.I.C., M.Inst. Met. and E. Mills, M.Inst. Met.

In the annealing of metals for high-quality work, scrubbing and pickling between workings were frequently necessary. These expensive cleaning treatments can now be obviated by annealing in a controlled atmosphere, and this article is mainly concerned with practical difficulties which arise in operating a furnace of this nature.

WITH not too strict an interpretation, "bright" heat-treatment has become an established fact in general engineering. Its scope extends from sheet and strip, rod and wire in short lengths or in coil, or in continuous lengths, to miscellaneous small components; it embraces the ferrous metals, irons and steels, magnetic alloys, stainless steels, the copper-rich alloys, brasses, bronzes and copper itself, nickel and nickel alloys such as monel metal, nickel silvers and cupronickels, and many others; and it caters for annealing, normalising and many hardening operations. In many of these instances, it is a fact that a truly bright product can be obtained relatively simply. In many other cases, a thoroughly satisfactory product is obtained, by no means bright in the eyes of the fastidious, but which can be truthfully described as "clean" annealed or heat-treated. In still other cases, a less satisfactory result is achieved due to a compromise between many conditions, but even so such efforts are by no means to be spurned, and they still correctly fall under the heading of "controlled atmosphere" heat-treatments. This is generally found to be so where a variety of treatments are imposed on a miscellany of components treated through a single general purpose channel type furnace of simple design. The subject of this article is mainly concerned with practical considerations of the difficulties which arise in operating a furnace of this nature.

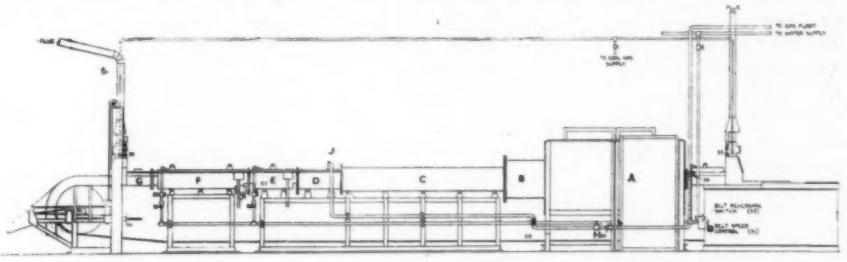


Fig. I.—General arrangement of furnace and cooling sections.

It appears to the writer that bright annealing can be successfully achieved with least difficulty either when the quantity of work to be handled is very small, or when the volume is great but the number of lines of product handled is very small. Again, it presents few complexities when one standard treatment is involved. But this demands a close study to determine the correct conditions necessary, and expenditure to put the results of the study into operation. In certain instances, to go to the full extent of this procedure is essential, as would seem to be the case with polished stainless steel; in others, as with steel, iron and copper, the conditions for the achievement of the bright result are not so arduous and are more readily attained with reasonable expenditure; again, with some metals, as for example, brass and nickel silver, it behoves one to be satisfied that a really bright result is essential and that a clean condition would not just as well serve the purpose.

The simplest conditions to cater for when employing open-ended tunnel type furnaces are those in which the work passes from the furnace proper to a rapidly cooled section in which exists a temperature gradient which keeps practically constant throughout the complete working period. These conditions are the most general in the softening treatments to which steel and strip, and inter-process pressings, and brass, copper and bronze on the non-ferrous side in similar forms, are submitted. In practically all these cases, a complete anneal is neither necessary nor desirable, the object being to relieve all strains and impart a predetermined amount of ductility. Most of these treatments are more of a normalising than a complete annealing process. In each of these instances, there exists a uniform temperature gradient in the furnace, and a uniform temperature in the cooling chamber is maintained throughout the working period without trouble. These are important considerations in determining the composition of the controlled gas atmosphere, its quantity and disposition of gas inlets. When once these factors are determined, they can be set and remain thereafter constant. Having eliminated these items from the list of variables, there are left only load and rate of travel for control by operators. Under these conditions, steel, iron and copper can be produced bright, and with a clean annealed condition for brass and nickel silver. On the other hand, where continuous tunnel furnaces are installed for purposes of achieving a full anneal as well as for normalising, and moreover, they have to cater for all the general run of metals which have to be treated in engineering, conditions are far from simple. Not only does the furnace temperature have to be fluctuated over the working week, which alone makes the retention of constancy in the cooling sectional most impossible, but also a graduated cooling section to cater for full annealing will vary in its temperature throughout the day when constructed in a simple commercial manner, unless expensive controlled heated zones are incorporated. To make the illustration specific, the manipulation of an electric tunnel furnace catering for both ferrous and non-ferrous work, for inter-process anneal and full anneal, in quantities up to 400 lb. an hour, and covering small articles up to 4½ in. × 16 in., will be discussed.

The general arrangement of the furnace proper and cooling sections are shown in Fig. 1. This follows well established lines, the principal features comprising:—

A. Furnace proper.
B. First cooling zone.
C. Second ,, ,,
D. Third ,, ,,
E. First water cooled zone.
F. Second ,, ,, ,,
G. Air cooled zone.
H and J. Inlets for controlled atmosphere.

Details of construction are of no present concern, but the extent to which the cooling zones are lagged can be appreciated from the diagram, while the limitations as to where gas can be introduced are also obvious. In the manipulation of such a furnace, it must be assumed that design is correct, being based on experience; quality of work produced with respect to extent of anneal will be

assured, being controlled by temperature, time and load. Appearance, however, with respect to "bright anneal" will depend upon a number of less precise factors, chief among which are :—

1. Cleanliness of work with respect to extraneous contamination, dirt, oil, grease, water, swarfe, &c.
2. Cleanliness of work with respect to oxide tarnish, rust, or corrosion products.
3. Composition of the controlled gas atmosphere with respect to degree of control that can be instituted at the gas plant controls.
4. Quantity of controlled gas introduced at the various inlets.
5. Air ingress with work or by other means.

These will be dealt with in the above order.

Cleanliness of Work—Extraneous Contamination

Work arriving at the furnace for treatment will consist of blanked and formed parts, pressings, machined articles, and occasionally, perhaps, strip and rod. These will obviously be contaminated by the oil and dust that was on the raw material in the "as received" condition ; by the shop oils, viz., soluble oil, sulphurised cutting oil, drawing compounds, tapping oils and greases ; by swarfe and metal dust from machine operations ; and by dirt picked up in transit through the shops, or swarfe from dirty bins in which transported. For simple shop manipulation, this miscellany of components must be cleaned by a reasonable commercial process. To obtain a clean anneal, the parts must be freed from all contamination. No one clean is available which is capable of removing in a rapid, economic manner such a diverse range of extraneous matter. A compromise therefore has to be effected, and the best results are secured by a sequence of operations, comprising a trichlorethylene vapour degrease to remove the bulk of the oil, a caustic soda or alkali rinse to remove soaps and solid dirt, followed by adequate water washing and drying. Even so, some soap may be left behind, some water remain in cups and some metallic particles trapped in holes or interstices. Where no soap greases are entailed, a rinse in liquid trichlorethylene, followed by a vapour degrease might be effective, and it is essential that any trichlorethylene vapour condensed in or on the articles should be removed prior to loading them into the furnace. In mass handling this is not always easy to guarantee.

If this cleaning is not carried out, or is indifferently performed, the extraneous matter must have some deleterious action upon the brightness of the work and perhaps upon the furnace (belt or elements) itself. Oil and grease carbonise ; if this occurs soon enough, and is not excessive, it will burn off at high temperature treatments, but will remain as a black deposit when low temperature treatments (e.g., brass and copper anneals) are involved. On the other hand, if the contamination is excessive, the burning of it will upset the balance of the controlled atmosphere and perhaps take this outside the permissible compositional limits. Soaps will inevitably leave an alkaline residue, which may be an adherent, difficult removable white deposit from lime base drawing compounds, or a glazed film giving a dirty tarnish from soft soap type of mixtures. Swarfe generally fuses and ruins appearance of surfaces, dimensions and thread forms, and prevents the mating of parts in subsequent assembly. Should steel parts be contaminated with brass, copper or aluminium dust and swarfe, these become welded on to the surface and give "spots" over which it is impossible to finish by electroplate processes. Moreover, the iron parts often get welded together, or to the belt, from this cause. Water evaporates and is a most undesirable constituent in the case of steel owing to its upsetting influence on the gas atmosphere. Trichlorethylene becomes cracked, attacks most metals, giving volatile chlorides which may deposit and ultimately short out the elements by bridging. Sulphur is deleterious to nickel alloy belts and elements, and gives undesirable strains on copper and brass which are not readily pickled off. The relatively high sulphur content of modern oils stresses the need for efficient cleaning prior to heat-treatment.

The point stressed at the moment is that perfect cleaning is desired, but in good commercial practice it is not obtained when dealing with miscellaneous work. Nevertheless, the utmost endeavour must be made to approach closely to the ideal, as any shortcomings are reflected in the result. The following warning is of practical interest. Work, cleaned and left lying exposed for some days before annealing, gathers dirt and dust ; this dirt and dust may still be found as an unsightly, dusty deposit on the work emerging from the furnace.

Cleanliness of Work—Oxide Tarnish and Corrosion Products

Corrosion deposits (e.g., verdigris on brass, rust on iron) have two main effects. Firstly, they contain oxygen, which upsets the gas atmosphere, and secondly, they produce work with a very bad appearance. In the case of brass, the green corrosion bakes to copper oxide which in turn becomes reduced to copper ; thus the work emerging has a red patch corresponding to the original green one. If heavily corroded, it may even emerge black, especially if shielded by other work. Rusty iron becomes reduced to a grey, amorphous-like mass. Apart from a general detraction from appearance, this reduced iron will not "pickle" by the recognised processes, and electroplating will not produce sound deposits. Heavy scale on iron blisters badly, and in any case the rough surface produced creates heavy wear on tools during subsequent forming or bending operations.

Gas Atmosphere Control

As before indicated, burnt coal gas will be the economic source of controlled atmosphere. The burnt gas composition is easily controlled from the proportions of gas and air employed, and the actual composition is rapidly checked by analysis. An ordinary Orsat apparatus is satisfactory for routine control, and 0·05% is the nearest reading one can easily obtain. Having satisfied oneself that no uncombusted air (oxygen) is present, control has to be made on either the CO or CO_2 value. One naturally uses the latter firstly for speed, secondly this represents the best oxidising constituent. Control of the gas plant is then possible within limits of plus or minus 0·1% CO_2, this tolerance being necessary owing to some variation in the temperature of the cracking chamber over the working day. As maintenance and control of gas and air cock settings are easily achieved, weekly gas analysis suffices. The particular gas composition depends upon construction of furnace and type of anneal.

In the case of iron or steel, if variation is permitted of the established gas composition, detriment to the product results. If the CO_2 limit is exceeded, oxidation occurs, and if fallen short of, carbon is deposited as soot. Incidentally, soot deposits more readily on ferrous alloys of high nickel content, especially those with a nickel content in excess of 35%.

The sooting phenomenon is effected by the design of the cooling chambers, the variation in the temperature gradient therein during the working day, and the points at which gas is introduced into the cooling chambers. There is not space available here to go into the question of gas equilibrium with temperature under the conditions obtaining, but sufficient has been said to show that a state of constancy is difficult to achieve. Even with accurate gas control to the limits specified, it is possible that many occasions arise at certain times of the working day, when the furnace is not continuously employed for long periods for one type of treatment, when perfect work *ceterus paribus* cannot be secured. It has to be remembered that such a furnace is merely an item in the production line and is not a laboratory equipment.

To take another illustration, in the case of brass it seems doubtful if perfectly bright brass can be produced with this type of equipment, but clean annealed brass is a simple proposition. Sooting and oxidising problems do not arise, because the gas composition can be operated at a much higher CO_2 value, and with a wider tolerance, so that any chance of sooting can be avoided by a wide margin ; also no gas need be introduced into the cooling section which again reduces sooting propensities.

Sulphur deserves mention. The equipment must include means of removing the bulk of the sulphur. For general purposes of producing bright annealed ferrous work (excluding stainless steel) or clean annealed non-ferrous metals, if the equipment contains bog ore chambers of sufficient capacity to remove the bulk of the sulphur, all reasonable requirements are met. If added security is required, an activated carbon purifier can be added. A weekly check on the sulphur content by passing the purified gas through lead acetate solution for 10 minutes, determines the efficiency of the bog ore chambers ; at the most, the first of a pair should require replenishing once in three months.

Water is a detrimental constituent and the burnt gas should be freed from entrained moisture prior to it entering the bog ore chambers by being passed through cooling towers, followed by further treatment by passage through a suitably designed baffle chamber. Excessive moisture precludes production of bright steel work, and actually promotes a black or red scale.

Quantity of Controlled Gas

In general, with a furnace open at both ends, the damper settings in the flues must be first established, and this has to be done in such manner that a steadily burning blanket is established at the entrance end, and a slight pressure at the exit end, the updraught at the flues being minimised. The maximum gas volume that can be pumped into the furnace to maintain the above condition is required.

For temperatures up to 600° C., the whole of the gas can be introduced in the furnace proper. Above this temperature, a portion must be introduced into the cooling section. These proportions must be determined by trial.

Ingress of Air

Ingress of air has to be avoided because obviously it upsets the gas composition. In practice it cannot be entirely eliminated, and it has to be minimised and controlled as far as possible, and the final decision on gas composition must be made after all practical precautions against air ingress have been installed. Some thought must be given to location and direct draughts eliminated. Fluctuating draughts must upset the holding of the gas atmosphere in the furnace, and they render effective setting of dampers impossible. Suitable screens must therefore be erected, and some form of curtain at entrance and exit to the tunnel employed. Even so, some suction of air occurs up the sides of the tunnel from the exit end. In furnaces of economic construction and size, this is generally evidenced by some slight oxidation or temper discoloration of iron and steel work on the sides of the belt. Usually this is not detrimental—the work as a whole being " bright" and to overcome it would uneconomic with little or no advantage to offset the cost.

Another source of air contamination which is unavoidable occurs when cupped-shaped articles have to be treated. However they are packed or loaded on to the belt, the air inside them is unavoidably carried into the furnace.

As can be seen from the foregoing, there are a considerable number of troubles to be overcome, and limitations to be considered, as far as general purposes annealing in controlled atmosphere furnaces is concerned. Even so, the results obtained, and the advantages gained thereby, more than justify the effort. In the eyes of the specialist, the product may be an indifferent " bright " anneal, but it is a *clean* anneal, which saves spoilation of work by heavy pickling, clogging of tools by detached scale, thereby improving tool-life, as well as monetary savings from pickling acid consumption, reduced pickling labour, porterage to the pickling shop, and an elevating moral influence from the mere production of something clean. It also makes for a cleaner heat-treatment shop and, where conveyerised furnaces are used, a regular flow of work in predetermined quantities, uniform quality of output, a minimum of labour effort and minimised heat loss from boxes, heating up and cooling down of barch type furnaces, &c. All this is effected by utilising cracked town's gas for the controlled atmosphere, the cracker being of simple construction and the removal of water and sulphur from the product also being achieved by simple means. A more complex and comprehensive system of purifying the cracked gases would be to remove water vapour more thoroughly and to ensure the complete removal of sulphurous constituents. Bearing in mind the initial additional plant expense and the quality of product required, as well as the degree of perfection of pre-cleaning the work itself, justification of these refinements is rather a moot point. On the other hand, it is anticipated that ammonia as the source of controlled atmospheres will in the future be available at a cost which will enable completely bright work to be produced at a reasonable price, but it would still appear some way ahead when plant and running costs for ammonia systems can profitably substitute town's gas for general purposes annealing in open ended furnaces.

Wolfram Discovered Near Sverdlovsk

Early this year, ores of the rare metal of wolfram, were discovered at the old goldfield of Berezovsk, near Sverdlovsk. So far wolfram has been found in four of the mines and about 100 tons of the ore have already been raised. The sampling of the ore shows it to contain a high percentage of wolfram.

Antimony from British Columbia

It is reported from Vancouver that the property of Reliance Gold Mines, Limited, in the Bridge River mining district near Minto, is likely to be re-opened for the purpose of mining antimony ore. A private company is being formed to lease the Wayside 180-ton mill, situated not far from Minto, in order to treat the Reliance ore.

Lord Rutherford of Nelson

THE unfortunate notice of the passing of Lord Rutherford, O.M., F.R.S., on October 19, was received just after we had gone to press with the October issue. Although our readers will be familiar with the work of this great scientist whom we could ill afford to lose, we should mention his more significant discoveries—those which had far-reaching effects on metallurgical theory and practice. Possibly, the outstanding researches which have direct interest to our readers are those of Lord Rutherford and his colleagues in respect of the transmutation of elements by electronic bombardment, and by α particles (electrically charged helium atoms), the elements being transmuted if the bombarding projectiles could penetrate and so change the essential constitution of the atomic nucleus of unstable radio-active elements.

He forecast the existence of neutrons prior to their detection by his colleague, Dr. J. Chadwick, only five years ago ; and this particle, possessing mass but no charge, was regarded by Lord Rutherford as one of the most significant media for atomic bombardment, as it could easily penetrate any atoms of matter in its path.

It is no exaggeration to say that the loss of this eminent scientist is one which will be felt throughout the metallurgical world just as much as it will be in the realms of physical science, but work will continue upon those now established theories which have thrown so much light on the problems of the nucleur structure of atoms and on the electrical nature of elements.

Correspondence

An Aid to Efficient Heat-Treatment

The Editor, METALLURGIA.

Sir,—Following the excellent article by Mr. W. F. Chubb, under the title "Causes of Trouble in Heat-treatment," published in your October issue, it occurs to me that a further alternative method of curing some of the difficulties which are continually being met during the ordinary practice of case-hardening or carburising mild steel may be of interest. This letter, however, does not imply that the suggestion embodied in it should be considered as an improvement upon that contained in Mr. Chubb's article.

Perhaps it will not be out of place to commence by shortly summarising some of the defects which are most common, and which cause most trouble in case-hardening practice. Firstly, may be mentioned the trouble generally caused by too high a temperature, resulting in a too rapid carburisation, with consequent high carbon content in the case, too thick a case, and brittleness, which throws much more intricacy on the subsequent heat-treatment. Secondly, there is the possibility of a too abrupt transition between case and core, with its subsequent peeling troubles; and thirdly, mention should be made of the heat-treatment process itself, which with plain carbon steels can easily produce much anxiety by reason of the dual treatment necessary—first, to correct the structure of the core, and then to put right the structure of the case.

Bearing all this in mind, as the practical man will of necessity do, I wish to put forward the suggestion that a considerable amount of these difficulties will be overcome, with, generally, a better material in the long run, and with very little or no extra net expenditure of capital, if from 3% to 5% of nickel is alloyed with the steel which it is desired to carburise.

To elaborate this suggestion a little, it is, of course, a very well-known fact that the addition of nickel to steel lowers the critical points quite considerably; in fact, about 10° C. lower for each 1% of nickel. That is to say, the temperature at which the steel will remain austenitic is lowered, so that the usual carburising temperature is very much farther into the austenitic region than is the case with the straight carbon steel. The result of this is that, other things being equal, it should be possible to carburise more quickly if there is an addition of nickel in the steel. Against this must be put the undoubted fact that nickel appears to prevent rapid diffusion of carbon into steel, so that the net result of these two factors is that the time for carburising will probably be about the same. It will, therefore, be logical to assume that, although the same length of time is actually being spent on the carburisation as time goes, there is, actually, less hurry taking place inside the steel itself, with the result that a more uniform case will be obtained, and there will not be the danger of the sharp transition between case and core.

Another favourable point is that, contrary to the plain steels at the elevated temperature used in carburising, nickel steel does not favour grain growth, with the result that the grain size of the carburised steel will not be nearly as great as in the plain steel, and, in fact, assuming the correct percentage of nickel is added, will be, without any heat-treatment at all, quite of moderate and reasonable size. A third point which arises from the argument just put forward is that the steel will remain much more uniform in every way, and there will not be that trouble so often experienced with ordinary carbon steels, the possibility of irregular results from steel of the same composition, and upon which the same degree of work has been expended.

To refer now to the heat-treatment cycle, because of the alteration in the temperature at which the transformation points occur, a slower rate of cooling can be employed in the quenching of the steel. This means that oil can be used as the normal quenching medium in place of water, which must, at its very best, not be as certain as oil-quenching. Furthermore, as a result of the effect of nickel on the grain size of the steel, and the consequent toughening of the material, it is possible to produce a perfect specimen of case-hardened steel with excellent case and thoroughly fibrous core with only one heat-treatment instead of the dual heat-treatment, almost always entirely necessary in the case of the plain carbon steels. Mr. Chubb can confirm this, as he was responsible for some very definite work on this point in connection with the Mond Nickel Co., Ltd., and a comparison of the mechanical properties obtained by him between steels which were given two heat-treatments and one heat-treatment only, proves the point very conclusively.

The final question arises—what percantage of nickel is necessary in order to obtain the results outlined above? A good many workers in this country, and in America, have, in my opinion, proved fairly conclusively that 3·5% is about the ideal figure. Certainly less than 2·5% would not give the desired effect, and while it has been suggested that as much as 5% should be used, it appears from the published results that a good all-round figure is 3·5%.

The opinion will undoubtedly be expressed that for the majority of purposes for which this class of steel is desired, nickel steel, even of 3·5%, is too expensive to be economical or competitive; but the answer to this objection appears to be that, in the first place, there is almost absolute certainty that a very superior product will result, thereby minimising the loss due to scrap or faulty material, and, secondly, there is an undoubted saving in the matter of the heat-treatment. The net result will, in the majority of cases, be very little different from the straight carbon steel; and after all, is it not better to pay a little more for an absolutely dependable article than a little less for a material which admittedly can be perfect, but which may, nevertheless, in spite of all the care expended upon it, be liable to imperfections without notice?

Yours, etc.,

Nov. 9th, 1937. C. HUBERT PLANT.

Effect of Neutral Solutions on Tin

Tin, alloys of tin and tin-coated metals are widely used because of their corrosion resistance in contact with practically neutral liquids such as water, milk and certain canned foods. Such corrosion as does occur takes the form of localised "black spots" which have been studied by Brennert whose findings were published some time ago. Further work on these spots has since been carried out by T. P. Hoar, M.A., Ph. D., and is now issued. In the present work, the influences of the surface condition of the tin and the concentration of chloride ion on black-spot formation have been investigated, and a detailed mechanism for the process is proposed.

The Surface of Tinplate

During the manufacture of tinplate there is a short period when molten tin and grease films are draining off the sheet. This period is too short for any large change in the distribution of the tin to occur but there are local effects which are responsible for the production of normal and potential pores. By applying surface tension and viscosity theory to the problem Dr. Bruce Chalmers has now provided an explanation of pore formation.

When for any reason there is a small non-reactive spot on the steel sheet the layer of molten tin tends to bridge it, but when the spot is over a certain size the film of tin breaks and forms a pore. Theoretical considerations show that unless the diameter of the non-reactive spot is greater than 0·6 of the local thickness of the tin coating a normal pore cannot be formed.

Copies of the above publications may be obtained free of charge from the International Tin Research and Development Council, Manfield House, 378, Strand, London, W.C.2.

DIE CASTING

The use of die castings for repetition work is sound economically and in a recent lecture on the subject before members of the Midland Metallurgical Societies, Dr. Arthur Street briefly described production methods, and gave particular attention to the choice of suitable alloys and factors that contribute to their successful application. The main features in his lecture are given in this article.

DIE casting has three striking features which make it attractive from an economic point of view. A die casting is cheap, it can be manufactured at high speed of output and, lastly, particularly in the pressure die-casting process, an accurate product is obtained. There are two chief methods of production, known as the gravity and the pressure processes. In gravity die casting the operations of the ordinary foundry are quite closely reproduced. The mould is opened and closed by hand, cores are inserted and extracted by hand, and the metal is hand poured. The only real difference between the making of a gravity die casting and a foundry casting is that the cores and the mould itself are permanent and made of steel or cast iron. On the other hand, the pressure process aims at being automatic in operation, and, so far as possible, the human element is reduced to a minimum. The mould is mounted on slides, one half being fixed and the other half moveable, and in modern machines this die is opened by a hydraulic plunger, and held together during the casting operation by the same means. Cores are inserted and withdrawn mechanically, and when the finished die casting is made it is ejected from the mould by automatically-operated ejector mechanism.

Gravity and Pressure Processes Compared

The fundamental difference, however, between the two processes is that in pressure die casting the metal in a liquid or pasty condition is squirted into the die under a very high pressure. There are very wide differences between the operation and products of the two processes, but, because, in this country, both gravity and pressure production are grouped under the general heading of "die casting," people often fail to realise how definite is the boundary between gravity and pressure die casting. Because the pressure casting is produced under extremely high working pressure its accuracy is superior to that of the gravity casting. It is found, for instance, that the gravity die casting is accurate to about 0·005 in. per inch, the accuracy of the pressure product is between 0·001 and 0·002 in. per inch. For the same reason, the finish of the pressure casting is brighter and sharper than the gravity die casting, although, of course, even a gravity casting has a better surface appearance than the ordinary foundry casting. It was usually easier to produce articles of thinner section by the pressure process, for instance, a zinc-base alloy can be die cast by the pressure process with a section of $\frac{1}{32}$ in., but to make a successful gravity casting, the wall thickness would probably have to be twice as much. On the other hand, it is frequently possible to obtain more complexity with the gravity die. Thus automobile pistons are usually made by gravity die casting, because this process allows the manipulation of built-up cores to make the undercut portion.

A gravity die is quite a simple affair—it does not have to be made with the extreme accuracy of the pressure mould, and because it is not subject to the erosive effect of metal under pressure, the gravity die can often be made cheaply of cast iron or mild steel. The setting-up time of the gravity die is small compared with that for the pressure mould, and because of that, coupled with the less expense of the gravity mould, the process can be applied with economic success for numbers of the order of 500 to 1,000 die castings.

The pressure die must be precisely made. In most cases it must be sunk in an alloy steel which is subsequently heat-treated. The die has to be provided with core-operating mechanism, ejector mechanism and water cooling. Further, it has to be set up with great care on a die-casting machine whose initial cost, running expenses and overhead expenses and overhead charges are considerable. It is not, therefore, usually economical to apply pressure die casting to small number production, and it should generally be reckoned that pressure die casting becomes of value when the quantities required exceed 5,000.

In pressure die casting, the metal enters the die in the form of a turbulent spray, and this metal is bound to be accompanied by the air which was previously contained in the mould and crucible, consequently, the venting of a pressure die must be skilfully arranged. In many cases, the joint at the two halves of the die is sufficient to allow the escape of the entrapped air, but for complex jobs special venting grooves have to be arranged. The skilful venting of a pressure die is one of the most important points in the production of a satisfactory die casting. In recent years, it has been realised that there is another important factor to be considered in the manufacture of a pressure die casting, and this is the working pressure. The condition of the metal when it enters the die may be compared with a sponge, and to wring this out completely necessitates a very hard squeeze, and in practice it is found that the application of high working pressure does mean that a more solid product is obtained. But this high pressure must be not used in an uncontrolled way, because if a die is unscientifically vented, badly made, and run in the wrong position, the effect of the high pressure would be to magnify the effects of these faults.

Choice of Suitable Alloys

In choosing an alloy suitable for die casting there are three main factors which have to be considered. These are: the raw material cost, the physical properties of the alloy rendering it suitable for the particular job, and the suitability of the alloy for production by die casting. Raw material cost must be considered, but it is not of paramount importance.

It must be remembered that because of the solidity and the fine grain of a die casting, its strength is usually higher than a corresponding foundry casting. Further, in most cases, subsequent machining operations are not necessary, so that quite often it is found that when a part is die cast its ruling section is deliberately reduced and, consequently, the amount of raw material in it became lessened. The main problem is the selection of an alloy which will die cast well and which will have properties that are worthy of the general finish of the die casting. It is found that amongst the aluminium alloys, the one which pressure casts best is that containing about 12% of silicon. This alloy happens to be one of the most expensive of the casting alloys, but because it can be pressure die cast so satisfactorily, and because its strength, corrosion resistance and other properties are very good, the fact that its raw material cost is high is not allowed to interfere with its extensive use in the die-casting industry.

As regards the physical properties, there are a number of questions which have to be considered, such as whether the alloy is strong enough, its capacity to withstand shock or alternating stress, whether it has to work in corroding conditions, or if it has to be soldered, or a special finish applied to the die casting. Both the user and the die-caster

should also consider whether the alloy will be suitable for production by die casting.

The thermal effect has to be considered, also the erosive effect and the solution effects of the liquid metal on the die steel. The alloy must be fluid at a temperature near its melting point, and it must not be hot short, otherwise it will crack under the constraint of the die. The alloy must solidify in just the right way to prevent air becoming entrapped in the die casting. Certain alloys, for instance, aluminium bronze, are more suited to the gravity process, while others, such as aluminium and zinc-base alloys, are essentially pressure die-casting alloys.

The freezing characteristics of the alloy are important factors in the consideration of the die-castability of an alloy. The alloy in the liquid or plastic condition is ladled into a metal container, and some method is adopted of injecting this metal at high velocity into the mould. As it enters the die the metal is in a dispersed and turbulent condition, but, with the continued application of pressure, all the air is forced away through the vents and the solidifying metal is forged into a solid casting. The cooling is extremely rapid because in most cases the die is water cooled. Three things, therefore, are of extreme importance : the alloy must be reasonably fluid at a temperature in the neighbourhood of its liquidus, also it must not be hot short at a temperature directly below its freezing point, and an alloy which is to be pressure die cast satisfactorily must have a short, though very definite, plastic range directly after freezing, so that it remains pliable while all holes were being squeezed out of it.

The section of a die casting should be arranged to be uniform, and most certainly there should never be any abrupt transition from a heavy section to a thin wall. Sharp corners should be avoided wherever possible as they introduce planes of weakness, and large areas or flat surfaces should, where possible, be broken up by ribbing. Cored holes when convenient should be arranged so that they are assembled in as few planes as possible.

Solvent Degreasing

VARIOUS details of the solvent degreasing process for the removal of oil and grease from metal articles, prior to electroplating or other finishing processes, are discussed by Mr. W. W. Davidson,* in which he dealt with the fundamental principles of equipment design and the characteristics of the stabilised, non-inflammable solvents.

The solvent degreasing process has been adopted by manufacturers of both ferrous and non-ferrous metal products, ranging from hypodermic needles to refrigerator boxes and large automobile body pressings. The process itself is quite simple, its basic function being to dissolve oil and grease by a stabilised non-inflammable solvent of chlorinated hydrocarbon in heated liquid or in vapour state. The three main types of degreasers now in general use are the vapour, the immersion and the spray types.

The simple vapour degreaser has a chamber in which the liquid solvent is boiled, an upper space to hold the hot vapours, and into which the work is lowered, the chemically-pure vapours condensing on the work, and a condenser to return the liquified solvent to the boiling chamber. This is a simple and relatively inexpensive apparatus and has the advantage that only pure vapours act upon the work, but the power of the vapour action depends greatly upon the difference in temperature between the metal and the vapour, the latter being at about 87° C. The washing effect is considerably diminished as the temperature of the work approaches that of the vapour. The complete cleaning cycle generally requires less than one minute. The vapour method is limited to about 10% of degreasing application.

The immersion degreaser gives a more positive cleansing action and also removes solid particles that are insoluble in the reagent. The use of this type is extensive. Generally, these machines have either two or three chambers, the sequence being immersion in the boiling solvent, immersion in clean solvent, and with three chamber types, followed by a pure vapour rinse. In a two-chamber machine the second chamber collects the condensed vapour and serves as a reservoir for clean solvent which, in turn, flows continuously over a dam into the heating chamber. The three-chamber type has the addition of the vapour chamber mentioned above.

In some machines, for use in particular where the roll of the boiling solvent would not be sufficient to remove insoluble material from the work, the sequence is vapour-spray-vapour. The work is first wet with the solvent vapours, then sprayed with hot solvent under pressure, and this is followed by a vapour rinse.

* Seventy-second General Meeting, Electro-chemical Society at St. Louis.

Mr. Davidson also dealt with the application of conveyers where justified by the volume of work, using mono rail or belt conveyers to make the degreasing machine fully automatic ; solvent stills for those types of work or installation where self-distillation may not be desirable ; a straightforward and simple method for field testing the degree of stabilisation of the chlorinated solvent, measured by alkalinity ; operating costs ; principles of design ; condenser construction and heating means. Gas and electricity are used successfully, but the most common means of heating is by steam at a pressure from 3 lb. to 20 lb., with steam coils welded to removable clean-out doors. In regard to heating, it is important to see that the inside bottom does not become insulated by insolvent matter, and thermostats are installed in the boiling compartment, these being set at a temperature of 121° to 132 °C., to prevent overheating.

Although various kinds of chlorinated hydrocarbons have been used for a number of years, there was the limiting factor of instability. The different grades of solvent for various types of cleaning and for use in different types of machines were also mentioned. Methods for eliminating impurities from, and stabilising, the chlorinated hydrocarbon have been discovered, and trichlorethylene is now accepted as the best and most suitable of these solvents for metal degreasing. It has a boiling point of 86° C., and requires only 0·25 cal. to raise one kg. 1° C., and 58 cal. to vaporise 58 kg.

South Wales Move To Attract Industries

Factories at rents from 6½d. per sq. ft. are offered by the Government-aided Treforest Trading Estate, the many facilities being described in a new information sheet for manufacturers just published. The buildings have complete central heating and electric lighting systems installed, and the rental includes land, complete with forecourt, paved yards, and estate road charges and an option for a reasonable period on unbuilt land adjoining the premises sufficient to accommodate a 50% extension of the factory. Under the De-rating Acts there is a 75% rebate on the normal rates and loans are made through the Treasury or the Special Areas Reconstruction Association for the purchase of plant.

An innovation in this country is that steam—like electricity, gas and water—is to be distributed to tenants by the Trading Estate Company, who are to buy it in bulk from the adjoining power station. Steam, in fact, will be " laid on." The information sheet, on which particulars of all services and charges can be seen at a glance, also includes a map of the area and a plan of the Estate. The standard factories on the Estate have a superficial floor area of 5,000 sq. ft. to 12,000 sq. ft. ; sub-division can be arranged down to 1,250 sq. ft.

Metal-Sprayed Surfaces in Relation to Lubrication

Sprayed metal is claimed to provide better bearing surfaces and experiments have shown that these surfaces working against each other will carry a higher seizure load and possess a lower coefficient of friction than when one of the metals is provided normally.

MUCH work has been carried out on metal-sprayed bearing surfaces, and the results have been so satisfactory that this method is now frequently used, particularly in making up worn journals. Another aspect of this subject, however, was discussed in a recent paper, before the Association of Metal Sprayers, by Mr. Harry Shaw, in which he stated that two sprayed metal surfaces, working against each other are quite satisfactory, and that, generally speaking, the seizure load is higher and the coefficient of friction is lower than when one of the metals is produced by normal casting and machining methods. A sprayed steel surface has pores so close together that they must be inter-connected, and the sprayed steel is in effect a fine sponge.

The use of sprayed white metal is of interest, but Mr. Shaw has not yet collected sufficient data to be able to make recommendations as to its use. Sprayed bronze, however, gives satisfactory results as a bearing metal; the point stressed being that it is important to have a really firm bond with the parent metal when bronze is sprayed on thin shells liable to distortion. According to Mr. Shaw sprayed journals are superior to ordinary steel journals for most bearing applications, this applies both to new products and to the building up of worn bearing parts. In all cases he refers to surfaces that have been deposited by the pistol method using the material in the form of wire.

The frictional and load-carrying properties of metal-sprayed steel shafts running in white metal bearings were investigated by the use of a Shaw frictiograph in which a two-inch-diameter shaft rotates in a complete bearing lined with any desired material, the bearing being pulled down on the shaft by a lever system connected with a load recorder. The main tests in this series were made at 445, 261 and 27 ft. per min. shaft speeds, under various loads; the coefficient of friction at each load being recorded. Lubrication was with a straight mineral oil for one series of tests, and with the same oil to which 0·2% of Acheson's colloidal graphite had been added. At a speed of 445 ft. per min. the ordinary steel shaft with plain oil seized at 900 lb. per sq. in. load in one test and at 1,000 lb. load in a second test. The addition of graphite to the oil raised the seizure load to 1,300 lb. per sq. in. The sprayed-steel shaft with plain oil and with graphited oil ran quite successfully at 2,000 lb. per sq. in. load (the maximum that could be applied in this test), and in another test set-up with a different mineral oil, the ordinary steel shaft seized at 650—750 lb., and the sprayed steel at 2,540—2,750 lb. The coefficient of friction of sprayed steel was mostly lower than the coefficient of friction of the ordinary steel by amounts varying between 5% and 30%, the coefficient being still further reduced by the addition of colloidal graphite to the oil.

Cut-off oil tests were also described, these showing that the sprayed-steel shaft would run for 22½ hours after the oil supply had been cut off before seizure took place, the ordinary steel shaft on the other hand, seized in about three hours; the greatly-prolonged duration resulting from the use of graphited oil was again demonstrated.

A very interesting series of tests were made on the crankshafts of 22 different engines, including private car, commercial vehicle and both petrol and Diesel 'bus units, to ascertain whether the sprayed metal would stand up to erratic and pulsating loads. There was no apparent difference in results from shafts with surfaces built up to either $\frac{1}{32}$ in. or $\frac{1}{16}$ in. thickness of coating.

Wear on the metal-sprayed journals of the petrol engines averaged 15% less than on ordinary journals, and 50% less in the case of the Diesel 'bus engines, whilst the wear on the contacting bearings was much less than on those contacting with plain journals—this averaging 40% less for the petrol engines and 55% less for the Diesel units.

Discussing lubrication, Mr. Shaw described the application of the Shaw contorograph which reproduces on a magnified scale the shape of the roughness of surfaces where the roughness exceeds a depth of one millionth of an inch. This machine uses a fine-pointed tracer which rises and falls in the roughnesses and oscillates a lever to which is attached a mirror. A beam of light is reflected by the mirror on to a sensitised film. Contorograms of typical machined surfaces were shown, and the author agreed that for general engineering practice the smoother the bearing surface the better its wearing properties; but he no longer held that opinion without qualification, for he had now investigated the very fine matt finish (comparable with frosted glass) and the porous finish such as sprayed metal.

Experiments had shown that the matt finish is more efficient than the mirror finish, but, unfortunately, the action of heavy loads polishes out this matt finish, unless a white metal of distinct duplex structure is used, or unless a colloidal graphited oil is used. Shaw contorograms of a lapped-steel sprayed surface showed that the surface is one mass of small pits, and that continued lapping or polishing does not remove these pits, but merely reveals fresh ones as the original ones disappear. Another advantage of matt finish is that it holds a certain amount of oil which is of great benefit both during the starting of the machine before the complete oil film has been formed and at times of extreme pressure when a normal oil film is liable to excessive thinning. When the matt finish is formed in part of pores beneath the surface the benefit is even greater.

Some specimens of sprayed metal that had been submerged in oil for 50 hours were found to absorb 10% (by bulk) of oil, the specimens being $\frac{1}{16}$ in. thick.

An interesting point was established as a result of investigations showing that wear, after short running periods, was found to be slightly greater on the metal-sprayed surfaces than on hardened steel, but that after continued running, this relation was reversed. By measurement of loss of weight, as well as reduction of dimensions, it was realised that the slight porosity of the sprayed steel allowed it to compress to a slight extent at the beginning of running, this later ceasing.

The new edition of the G.E.C. catalogue dealing with ironclad switchgear shows how a very wide range of control and protective gear now covers the greatly-increased requirements of modern electrical installations. In addition to fuse and switch gear, the new catalogue contains full details of enclosed (air-break and oil-immersed) circuit breakers for medium voltages, earth leakage circuit breakers, air thermostats, small transformers up to 4½ kVA, cable box and packing glands, busbar chambers and various accessories.

The book is double punched for loose-leaf binding and is also corded for hanging. (The General Electric Co. Ltd. Magnet House, Kingsway, London, W.C. 2.)

New Roughing Mill at London Works (Barlows) Limited

FOR producing angles and sections for structural work bedsteads, etc., London Works (Barlows) Limited, of Oldbury, Birmingham, have recently installed a new 14-in. three-high roughing mill, which works in conjunction with a 10-in. angle and section mill. A general view of the plant is shown in Fig. 1. The contract was placed with the Brightside Foundry and Engineering Company Ltd., who entrusted the order for all electrical equipment to The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C. 2.

The new mill runs continuously night and day, and has an output of 100 tons of angles every 24 hours. It is driven through gearing by a 250-h.p. slipring motor of the protected type, designed to run at 485 r.p.m. on a 400-volt three-phase supply. The motor was built at the G.E.C. Engineering Works, Witton, Birmingham, and follows the company's standard design for heavy-duty slipring motors. The machine is of particularly strong construction, both electrically and mechanically to meet the exacting requirements of rolling-mill drives. It is controlled by a standard oil-immersed stator switch and liquid starter. Protection of the motor is afforded by two over-current relays and a no-volt trip which are embodied in the stator switch, while the necessary instruments, including an ammeter, voltmeter and watt-hour meter, are mounted on top of this switch.

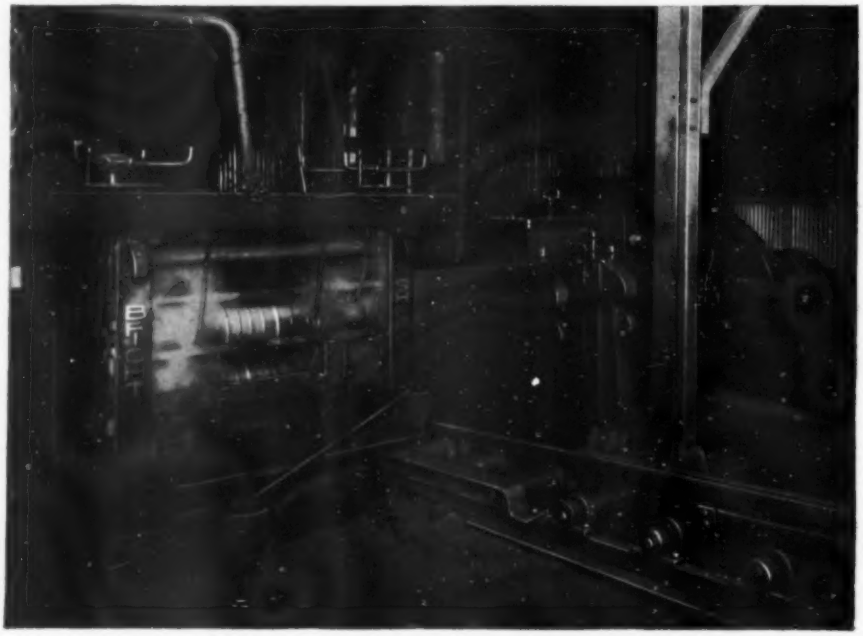


Fig. 1.—General view of the new 14-inch three-high roughing mill driven by a 250 h.p. G.E.C. motor at London Works (Barlows), Ltd.

Acknowledgment is due to Mr. A. N. Mayer, managing director of London Works (Barlows) Limited, and to the Brightside Foundry and Engineering Co., Ltd., for permission to refer to this development.

Electro-Magnetic Slip Couplings for Use with Geared Diesel Engines for Ship Propulsion

HIGH-SPEED geared Diesel engines allow a saving in weight and headroom as compared with the ungeared type, but their use involves some type of flexible coupling between the engine and gear, to avoid transmission of the torque impulses. The type of coupling described by Mr. G. L. Metz, in a paper under the above title, which he read recently before the Institute of Marine Engineers, also allows easy uncoupling by merely operating a switch, so that an engine can be shut down for overhaul, or for cruising at reduced speed; the remaining engines, geared to the same propeller continuing in operation. Other advantages claimed are absence of wear; safeguarding of the remainder of the installation, due to limited ability of the coupling to carry overload, the maximum torque that can be transmitted being about twice the normal; and absence of necessity for perfect alignment between the two halves of the coupling.

In general principle the coupling follows the induction motor, except that the "stator" rotates as well as the rotor, normally at very nearly the same speed. The primary, on the gear shaft, carries electro-magnets, excited through slip-rings, whilst the secondary, on the crank-shaft, has a short-circuited squirrel-cage winding. The excitation is by direct current at any available voltage. The normal slip is about 1·5%, and the characteristics of the coupling are such that any value of torque can be transmitted irrespective of the revolutions per minute. The efficiency of the coupling itself is 98% to 99%, and a further 1% to 2% is lost in the form of excitation energy derived from the auxiliary dynamo. The torsional oscillations of the engine itself are practically unaffected by the coupling, but only slight oscillations are transmitted through the coupling to the gearing and screw-shaft. There is no appreciable variation in slip during manœuvring, and the method of engine control is not affected by the use of the coupling.

Under abnormal conditions it is possible for the two halves of the coupling to get "out of step" and operate at a greater relative slip. The slip is shown by a stroboscope, and since the slip depends on the torque, the torque and power can be deduced from a knowledge of the slip and excitation current. As an alternative to the normal method, rapid manœuvring can be effected by keeping the engine running and using the coupling switch. A single screw two-engine installation of 2,100 b.h.p.—engine r.p.m. 300, propeller r.p.m. 130—and a 4,400 b.h.p. installation consisting of four engines running at 300 r.p.m., and geared to a single screw at 90 r.p.m., are described.

"'Ironex' Electrodes" is the title of a 12-page booklet issued by Murex Welding Processes Ltd., Ferry Lane Works, Forest Road, London, E. 17. These electrodes are of the Murex extruded type with special patented coating that embodies a new and highly efficient principle of protection. The booklet describes how metal losses due to volatilisation and splashing are minimised by the use of "Ironex" electrodes, and a table shows the results of experiments on mild steel butt welds of varying sections; results of volatilisation tests are shown in in a second table, following which it is claimed that these electrodes will deposit by weight approximately 14% or more weld metal than mild steel electrodes having non-metallic coating.

Business Notes and News

Heavy Accumulation of Iron and Steel Orders

The iron and steel industry continues to show great activity, but there is a welcome lull in new business which is enabling the various producing works to reduce the heavy accumulation of orders on their books. It is apparent, however, that most of the steelworks will carry over, at the end of the year, a very large tonnage of work for execution in 1939. The demand for practically all descriptions of finished steel material is unrelaxed, and a certain amount of business has been accepted for delivery over the first half of next year.

Consumers of pig-iron are more comfortably situated than for a long time, while steel makers are receiving sufficient hæmatite and basic iron to fill their current needs and appear to be less nervous regarding the future. In the semi-finished steel department supplies show a tendency to expand.

Export business remains quiet, but British works have considerable tonnages to deliver against existing contracts.

New Wolfram Company

Under the name Keza, Ltd., a new British-controlled wolfram mining company has been formed with a nominal capital of £100,000 in 400,000 5s. ordinary shares. The company is acquiring wolfram interests in Portugal and proposes to instal a wolfram crushing and treatment plant with a capacity of 300 tons of concentrates per annum. This is to be a "pilot" plant, and further units may be added after production has commenced, which is expected to be in about six to eight months' time. The total cost of reaching the production stage has been estimated at £10,000, which is being subscribed by the directors and their friends. It is intended to apply for permission to deal in the shares in due course.

Ford's New Gasometer

The latest constructional development at Ford Works, Dagenham, takes the form of a gigantic new gasometer, with a capacity of 2,000,000 cub. ft. This new feature is over 185 ft. in height, and will hold gas produced in the Ford blast-furnace which heats the coke ovens designed to carbonise 900 tons of coal a day. Part of the gas production of the coke ovens is distributed to domestic consumers through the Gas Light and Coke Company, of Beckton.

The new gasholder is notable as being the first in this country to be of partly welded construction, and as a result is attracting considerable attention from gas engineers. An external lift gives access to the gallery on the roof of the structure. The gasometer is of the Klonne waterless type, and is being erected by Messrs. Horseley Bridge and Thomas Piggott, Ltd., Horseley Works, Tipton, Staffs.

Japanese Copper Works

In Japan one of the largest copper works is that of the Sumitomo Metal Industries, each of whose factories has its own laboratory. Actually, the principal subjects under review at the laboratory of this company's Osaka copper works are copper, aluminium, magnesium, nickel and other alloys, whilst special steel plates are also under investigation. The laboratory personnel numbers 150, divided into two groups, one for research and the other for testing.

The objects of the research department are stated to be the production of better alloys, the improvement of existing alloys, improvement in manufacturing methods and the testing of products including chemical analysis and mechanical tests.

The company produces aluminium alloys, magnesium alloys and copper alloys. The magnesium alloy developed is known as Selktron No. 4 (S E·4), and the copper alloy is Albrac, this being used for shipbuilding and electrical generating plant; A R, an acid-resisting alloy for the pipe industry; Special Silzin (S S Z) with high tensile strength and resistance to corrosion; Highralbronze (H B1–H B4), a bearing metal of special aluminium bronze which is credited with a Brinell hardness of 400; and Berychrome No. 1, containing beryllium and chromium, and having high electridal conductivity and tensile strength.

Very big claims indeed are made for the company's development of Super-Duralumin alloys.

Lightalloys Extensions

At the recent annual general meeting of Lightalloys, Ltd., reference was made by the chairman, Capt. Oliver Lyttleton, D.S.O., M.C., to plant extensions which have been undertaken during the last two years. The total sum expended is approximately £36,500. Of this sum about 50% has been spent in additional engineering shops and plant and the remainder on additional foundry facilities.

As is well known, this firm was responsible for the introduction into this country of modified aluminium silicon alloy. This alloy, "Alpax," is now very widely used. As a result of considerable experimental work it has been found that, by adding certain elements to this alloy and then subjecting it to heat-treatment, certain of its physical properties are greatly improved. The engineering department is to a large extent employed in the production of patented products, and it is noteworthy that the company has recently secured the largest contract so far placed in this country for railway doors and railway carriage fittings.

An order is being executed for "Alpax" doors for the 100 railcars at present being built for the Buenos Aires Great Southern Railway, and the company has recently completed contracts for the London and North-Eastern Railway and the London Midland and Scottish Railway for the whole of the doors of the new rolling stock to be employed on their electrified Tyneside and Wirral systems.

Shipbuilding Activity on North-East Coast

Greater activity is being enjoyed in shipbuilding yards on the North-East Coast than has been experienced for many years. During the last year or two there has been a gradual upward trend in keeping with other shipbuilding areas, and recent orders placed gives further evidence of improvement in the industry. The ships ordered include a collier of 3,200 tons, to be built by Messrs. S. P. Austin and Son, Sunderland, with engines by the North-Eastern Marine Engineering Co., Ltd., Wallsend, for the London Power Company; a steam tanker, 255 ft. long to be built by Messrs. Smith's Dock Co., Ltd., Southbank; a vessel for Greek owners, to be built by Messrs. W. Gray, of West Hartlepool; and another vessel, details of which are not yet announced.

Gas Industry Research Needed

Fundamentally, the electrical engineer has a more difficult task than the gas engineer, said Sir Frank Smith, Secretary of the Department of Scientific and Industrial Research, at a recent meeting of delegates to the autumn research meeting of the Institution of Gas Engineers, because he deals with a single entity. Research in the electrical industry is directed to ends which are likely to lead to increased demand for current and for the transport of electricity.

Gas engineers are not faced with the difficulty of one entity, but have many—coal, coke, benzole, and so forth—every one of which can be transformed into several products. On the extent to which these things are produced and transported economically may largely depend the success of the gas industry in the future. For these reasons the gas industry even more than the electrical industry should spend money on research. Sir Frank suggested that the industry, taken as a whole, was not spending enough on research and that it should make up its mind to get more knowledge.

Jarrow Steelworks Plan

The Commissioner for the Special Areas of England and Wales announces that he has now arranged to lease the land he is acquiring at Jarrow to a new company which is being formed to build and operate a plant for the manufacture and rolling of steel. To induce the company to establish the proposed undertaking at Jarrow the Commissioner has offered it contributions in respect of rent, rates and income-tax under the powers conferred on him by the Special Areas (Amendment) Act, 1937, and the Treasury have agreed to the Commissioner's recommendation for remission of National Defence Contribution.

The Treasury have agreed to provide loan money from the fund created under the Act, and the Nuffield trustees are taking a large number of shares. The balance of the total capital of £1,000,000 required for the proposed undertaking is being subscribed in part by the Consett Iron Company and in part through the intermediary of the Bankers' Industrial Development Company.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£92	10	0
Chinese		76	0	0
Crude		47	0	0

BRASS.

Solid Drawn Tubes	lb.	0	0	11¾
Brazed Tubes	„	0	1	1½
Rods Drawn	„	0	0	9¾
Wire	„	0	0	8½
*Extruded Brass Bars	„	0	0	5½

COPPER.

Standard Cash		£39	2	6
Electrolytic		39	9	0
Best Selected		44	5	0
Tough		43	15	0
Sheets		73	0	0
Wire Bars		45	10	0
Ingot Bars		45	10	0
Solid Drawn Tubes	lb.	0	1	0¾
Brazed Tubes	„	0	1	0¾

FERRO ALLOYS.

‡Tungsten Metal ° Powder nominal	lb.	£0	9	0
‡Ferro Tungsten ° nominal	„	0	8	6
Ferro Molybdenum °				
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 12/– per unit	ton	34	15	0
NOMINAL: 4–6% Carbon, scale 8/– per unit	„	24	5	0
NOMINAL: 6–8% Carbon, scale 7/6 per unit	„	24	0	0
NOMINAL: 8–10% Carbon, scale 7/6 per unit	„	24	0	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	„	37	0	0
Guar. max. 1% Carbon. scale 13/– per unit	„	39	0	0
§Guar. max. 0.5% Carbon, scale 13/– per unit	„	49	0	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	„	0	2	5
§Ferro-Vanadium 25–50%	„	0	12	8
§Spiegel, 18–20%	ton	9	15	0
Ferro Silicon—				
Basis 10%, scale 3/– per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	„	12	0	0
45/50% basis 45%, scale 5/– per unit	„	12	0	0
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METALLURGIA. Contents. For NOVEMBER, 1937.

	Page
Rolling Mill Machinery Manufacture. *Reference is made to progress of rolling mill manufacture, especially the design and construction of cold-rolling mill machinery, and to recent works extensions.*	1–4
Research and the Foundry	5
Developments in Tube Manufacture	6
Chromium-Manganese Steels as Heat-Resisting Steels. By J. H. G. Monypenny, F.Inst.P. *The structural characteristics of chromium-manganese steels are discussed, more particularly as affected by prolonged heating at high temperatures.*	7–12
Resistance Welding Progress	12
High Duty Bronzes. By F. Hudson. *In this article the author deals with alloys containing an appreciable quantity of tin, which constitute the true bronzes.*	13–16
Molybdenum in Tool Steels. By W. F. Chubb. *The fundamental principles upon which the use of molybdenum in tool steels is based are briefly described, and details are given of the properties obtainable in steels employed for these purposes.*	17–18
A New Industrial Map of the U.S.S.R. By a Special Correspondent. *The widespread industrialisation of the formerly backward areas, and the economic development of the various regions are reviewed.*	19–20
Mechanical Properties of Copper-Tin Alloys at Elevated Temperatures. *The results of an investigation to establish a reliable means of comparison between four standard tin bronzes and other bronzes are discussed.*	21–22
Hiduminium RR77. *A new alloy in the Hiduminium series which possesses unique properties. It has been developed for use in highly stressed parts.*	22
Reviews of Current Literature. *Arc-welding Handbook. Transactions A.I.M.E.* (1937). Vol. 124.	23–24
Controlled Atmosphere Annealing. By E. C. J. Marsh, B.Sc., A.I.C., M.Inst. Met., and E. Mills, M.Inst. Met.	25–27
Correspondence. *An aid to more efficient heat-treatment.*	28
Die Casting	29–30
Solvent Degreasing	30
Metal-Sprayed Surfaces in Relation to Lubrication. *Experiments have shown that sprayed-metal surfaces, working against each other, will carry a higher seizure load and possess a lower coefficient of friction than when one of the metals is produced normally.*	31
New Roughing Mill	32
Electro-Magnetic Slip Couplings, for Use with Geared Diesel Engines	32

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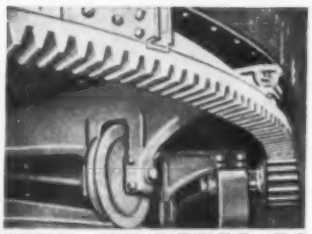

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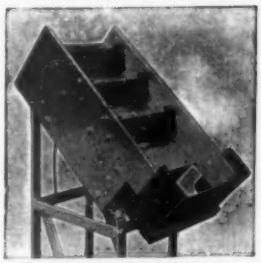

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Index to Advertisers.

	PAGE
Aluminium Union, Ltd.	28
Amalgams Company, Ltd.	32
Associated British Machine Tool Makers, Ltd.	22
Barrow Hæmatite Steel Co., Ltd.	Back Cover
Birmingham Electric Furnaces, Ltd.	—
Bradley and Foster, Ltd.	—
British Acheson Electrodes, Ltd.	24
British Aluminium Co., Ltd.	Front Cover
British Commercial Gas Association	25
British Furnaces Ltd.	19
Burdon Furnace	—
Calorizing Corporation, Ltd.	—
L. Cameron & Son, Ltd.	—
Carborundum Co., Ltd.	3
Clifford, Chas., and Son, Ltd.	24
Demag, A.G.	18
Demag Elektrostahl	26
Doncaster, Daniel Ltd.	7
Dowson & Mason, Ltd.	—
Dunford & Elliott	—
Edgar Allen & Co., Ltd.	10
Ehrhardt & Sehmer	—
Electric Furnace Co., Ltd.	13
Electroflo Meters Co., Ltd.	—
Electromagnets Ltd.	33
English Steel Corporation, Ltd.	Inside Back Cover
Ether, Ltd.	26
Eumuco Ltd.	—
Firth, & Brown, Ltd.	—
Firth-Vickers, Ltd.	—
General Electric Co., Ltd.	—
Gibbon Bros., Ltd.	—
Charles Griffin & Co., Ltd.	33
Harrold, Charles and Co., Ltd.	20
Harrison & Son (Hanley), Ltd.	—
High Duty Alloys, Ltd.	5, 6, 27
Howden, T. C., and Co.	32
Imperial Chemical Industries, Ltd.	12
Incandescent Heat Co., Ltd.	—
Integra Co., Ltd.	—
Kasenit Ltd.	12
Kent, George, Ltd.	—
Krupp Grusonwerk A.-G.	—
Magnesium Castings & Products Ltd.	7
Manganese, Brass & Bronze Co.	31
Marshall and Co.	—
McKechnie Brothers, Ltd.	Inside Front Cover
Metalectric Furnaces, Ltd.	26
Metro-Vickers, Ltd.	9
Mills Wm. Ltd.	14
Mond Nickel Co., Ltd.	17
Morgan Crucible Co., Ltd.	—
Northern Aluminum Co., Ltd.	11
Ofag Ofenbau	16
Priest Furnaces, Ltd.	20
Reynolds Tube Co. Ltd.	Inside Front Cover
Rheinische Walzmaschinenfabrik	16
Robertson, W. H. A., and Co., Ltd.	14
Rudge-Littley, Ltd.	—
Sanderson Bros., and Newbould, Ltd.	30
Schmitz A.G.	24
Schloemann, A.-G.	4
Shorter Process Co., Ltd.	32
Stein, J. G., & Co., Bonnybridge, Scotland	30
Sterling Metals, Ltd.	—
Siemens Schuckert.	15
Thermal Syndicate, Ltd.	32
United Steel Companies, Ltd.	21
Ungerer, Karl Fr.	23
Wallwork, Henry, and Co., Ltd.	—
Wild-Barfield Electric Furnaces, Ltd.	8
Wiggin, Henry Ltd.	—

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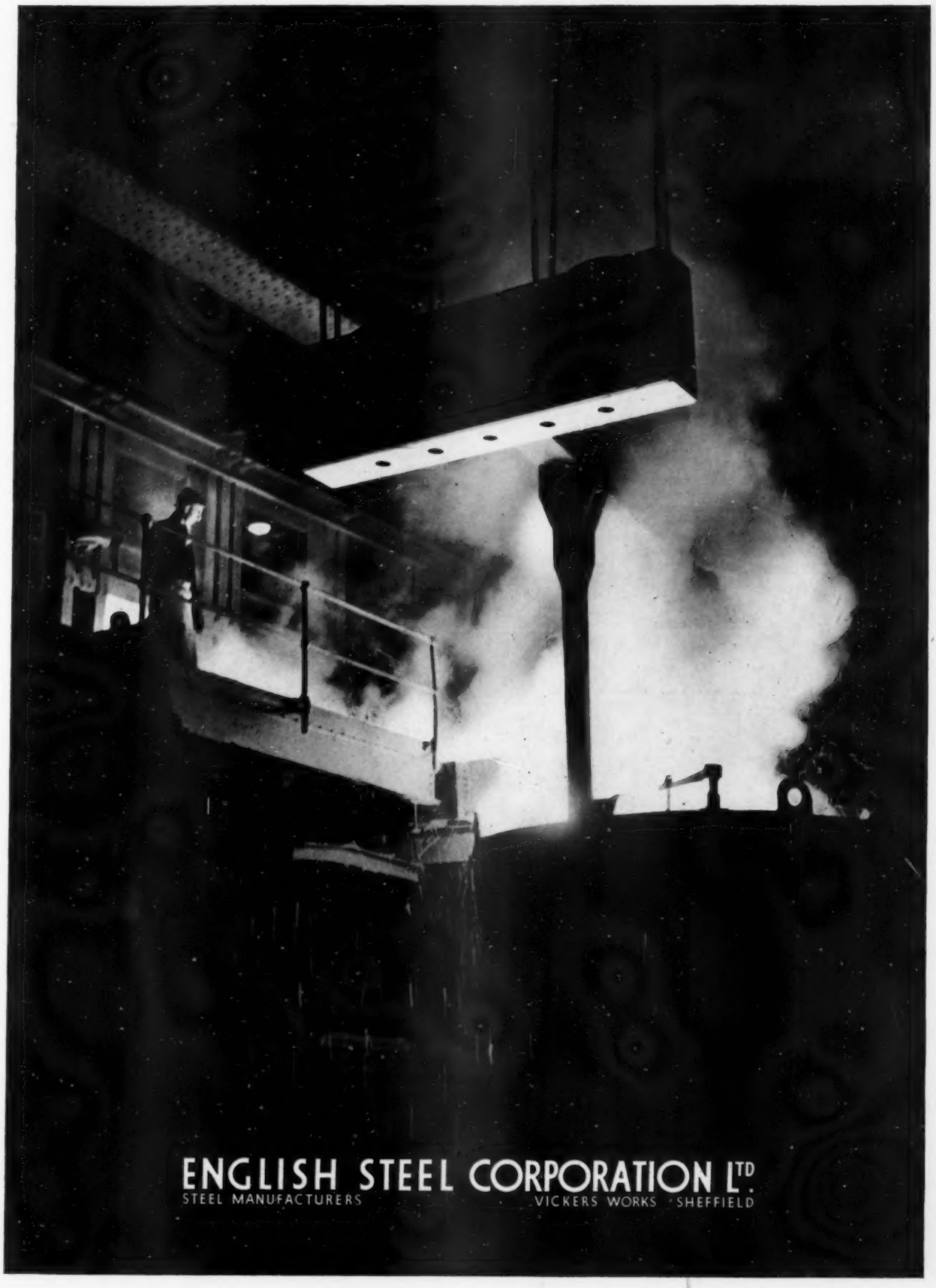

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